Horizon 2020 Societal challenge 5: Climate action, environment, resource efficiency and raw materials

BINGO

Bringing INnovation to onGOing water management –

a better future under climate change

Grant Agreement n° 641739, Research and Innovation Action

Deliverable number:	**D4.2**
Deliverable name:	Risk identification: Relevant hazards, risk sources and factors
WP / WP number:	WP4: Assessment of Impacts of extreme weather events
Delivery due date:	Project month 30 (01/01/2018)
Actual date of submission:	1st version 22/12/2017; 2nd version 24/05/2018
Dissemination level:	Public
Lead beneficiary:	LNEC - AQUATEC
Responsible scientist/administrator:	Beniamino Russo, Pablo Sánchez, Fernanda Rocha, Teresa Viseu
Estimated effort (PM):	8.71 PM
Contributor(s):	Alberto Freitas (DGADR), Ana Luís (EPAL), André Fortunato (LNEC), Angel Villanueva (AQUATEC), Basilio Martins (EPAL), Beniamino Russo (AQUATEC), Clemens Strehl (IWW), Eduardo Martínez (CETAQUA), Elsa Alves (LNEC), Emmy Bergsma (KWR), Erle Kristvik (NTNU), Fernanda Rocha (LNEC), Henk-Jan van Alphen (KWR), Juliane Koti (IWW), Marc Scheibel (Wupperverband), Marta Rodrigues (LNEC), Pablo Sánchez (AQUATEC), Paula Freire (LNEC), Paula Lorza (Wupperverband), Pedro Brito (DGADR)
Estimated effort contributor(s) (PM):	AQUATEC: 3.0 PM, CYI: 0.5 PM, CETAQUA 0.2 PM; DGADR: 0.2 PM, EPAL: 0.1 PM, IACO: 0.5 PM, IWW: 0.3 PM, LNEC: 1.61 PM, NTNU: 1.2 PM, KWR: 1 PM, WV: 0.1 PM.
Internal reviewer:	Henk-Jan van Alphen (KWR)

Note: This version of D4.2 includes changes implemented in order to address the comments from the review of the second reporting period.

Changes with respect to the DoA
Not applicable

Dissemination and uptake
Public

Short Summary of results (<250 words)

Deliverable 4.2 – "Risk Identification: Relevant hazards, risk sources sites, and factors" was developed by LNEC, AQUATEC, IWW, NTNU, KWR, CYI and local partners in the framework of WP4 ("Assessment of the impacts of extreme weather events") and within Task 4.2 - "Risk identification", led by AQUATEC with the support of the WP4 leader LNEC. This deliverable aims at identifying and describing the risks generated by extreme weather events at each BINGO research site. Relevant hazards (from WP3) have been identified and potential events have been explored within BINGO under the context established in previous Task 4.1. This report concerns the first step (risk identification) of the risk assessment within the risk management process defined in the D4.1 according to ISO 31000:2009, while risk analysis and risk evaluation will be treated in the Task 4.3. Jointly to Deliverable 4.1, this deliverable contributes to provide important inputs and basic information for the tasks to be developed in WP5.

This version of D4.2 includes changes implemented in order to address the comments from the review of the second reporting period.

Evidence of accomplishment
Report

Contents

LIST OF FIGURES

LIST OF TABLES

ACRONYMS

ABLGVFX	Associação de Beneficiários da Lezíria Grande de Vila Franca de Xira (Association of Beneficiaries of Lezíria Grande de Vila Franca de Xira)
APA	Agência Portuguesa do Ambiente (Portuguese Environment Agency – National Water Authority)
ARBVS	Associação de Regantes e Beneficiários do vale do Sorraia (Association of Irrigators and Beneficiaries of Sorraia Valley)
ARH	Administração da Região Hidrográfica (River Basin District Administration or Hydrographic Region Administration)
ARH_TO	Administração da Região Hidrográfica do Tejo e Oeste (River Basins District Administration of Tagus and West)
BWD	Bathing Waters Directive
BINGO	Bringing INnovation to onGOing water management
CC	Climate change
CSO	Combined Sewer Overflows
CY	Cyprus
DE	Germany
DGADR	Direção-Geral de Agricultura e Desenvolvimento Rural (Directorate General for Agriculture and Rural Development)
EDP	Eletricidade de Portugal (Electricity of Portugal)
EPAL	Empresa Portuguesa das Águas Livres – Grupo Águas de Portugal (EPAL – Public Water Supply Company to Lisbon and all the right margin of lower Tagus river)
EU	European Union
ISO	International Organization for Standardization
IWRM	Integrated Water Resources Management
LGVFX	Lezíria Grande de Vila Franca de Xira
LVT	Lezíria do Vale do Tejo
NL	Netherlands
NO	Norway
PIP	Public Irrigation Perimeter
PT	Portugal
PWS	Public Water Supply
RMP	Risk Management Process
RS	Research Site
SP	Spain

WTP	Water Treatment Plant
WP	Work package
WR	Water Resources
WRM	Water Resources Management

1 INTRODUCTION

1.1. Background

The ultimate objective of the BINGO project is to provide risk adaptation strategies for climate change related challenges, validated by a common standard risk management framework, to support decision making. The risk management approach followed in BINGO is based on ISO 31000:2009

The Risk Management Process (RMP) includes several key steps, each of them with a significant purpose, that, when undertaken in sequence, enable continual improvement in decision-making (Figure 1.1): i) establishment of the RMP context; ii) risk assessment (consisting of risk identification, risk analysis and risk evaluation; iii) risk treatment. Communication and consultation as well as monitoring and review are continuous tasks in the overall RMP process.

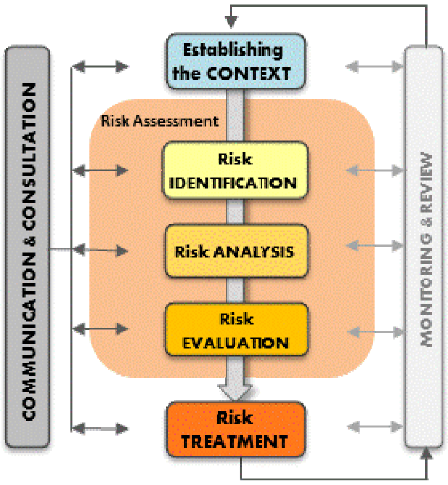


Figure 1.1: The Risk Management Process (ISO 31000:2009)

The BINGO project follows a risk approach methodology but it is not a real entity managing its own risk. Therefore, it is necessary to adapt many concepts, approaches and methodologies of a risk management process into the BINGO project. In Rocha (2016), the phases of the risk management process are identified, as well as some suggestions for project adaptation.

The objective of Work Package 4 (WP4) is to perform risk assessment for each BINGO research site (RS). The purpose of Task 4.2 of Work Package 4 (WP4) is to perform risk identification, the first step of the risk assessment process that is the ultimate objective to be achieved in Task 4.3 (Risk Analysis and Risk Evaluation). Once the risks are identified, analysed and evaluated, it is possible to prioritize them in order to support decision making in the definition of adaptation strategies. Risk assessment will provide decision support on the risks that need treatment (risk higher than tolerance level) and rank them by level of magnitude. It will therefore support decision on climate change strategies to be proposed in WP5.

1.2. Structure of the document

The main purpose of this report is to present the results of the risk identification step for all risk management processes of each BINGO research site.

Chapter 2 provides the background of BINGO research sites as well as a summary of previous tasks outputs, relevant to risk identification.

In Chapter 3, conceptual definitions and some guidance on how to perform risk identification are presented.

Chapters 4 through 9 present the risk identification affecting each objective set for the BINGO research sites. Each chapter has been the responsibility of the respective BINGO scientific partner team.

In Chapter 10 a summary is provided: similarities and singularities between the research sites are identified and analysed. This summary is presented bearing in mind the requirements of work packages 4.3 and 5.

1.3. BINGO common language

Whenever possible, the risk definitions from ISO Guide 73:2009 are used, aiming to achieve a BINGO project risk common language. Complementary terms were defined among partners when considered necessary. This information is included in the BINGO GLOSSARY presented in Annex I of Deliverable 4.1. A selection of the terms relevant to risk identification is presented in the following paragraphs, to be handy. A more exhaustive list of definitions is presented in the Annex I of this report.

Risk is the effect of uncertainty on the achievement of the objectives of an organization.

Uncertainty is the state of deficiency of information related to the understanding or knowledge of an event, its consequences, or likelihood. Uncertainty exists when we do not have any or have only partial information about future events. Examples of uncertainty are: not enough information about the causes, although we may (or may not) have adequate information about possible events and their consequences; not enough information about the events, knowing the causes; not enough information about the consequences, although we have adequate information about the causes or the events. It is important to recognise uncertainty, as it defines the quality of our knowledge concerning risk. Uncertainty may affect both the likelihood of hazard conditions occurring and the consequences of those hazard events. Figure 1.2 provides a summary of possible sources of uncertainty related to climate change risks.

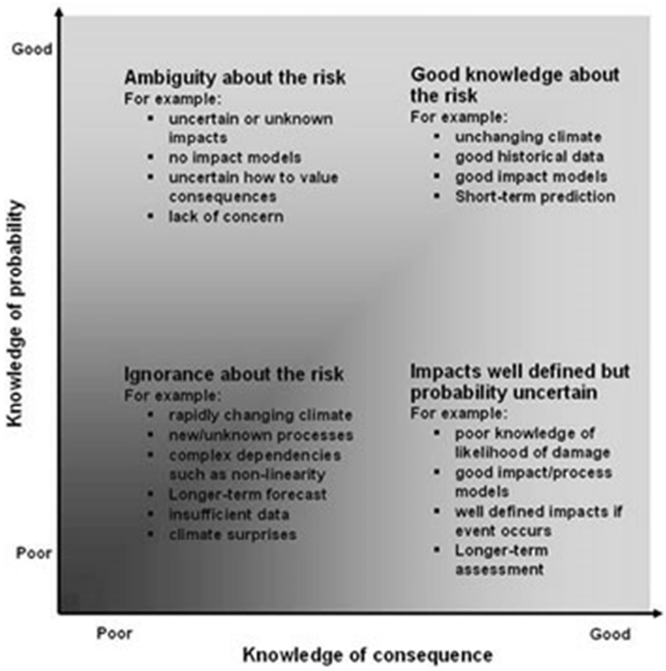


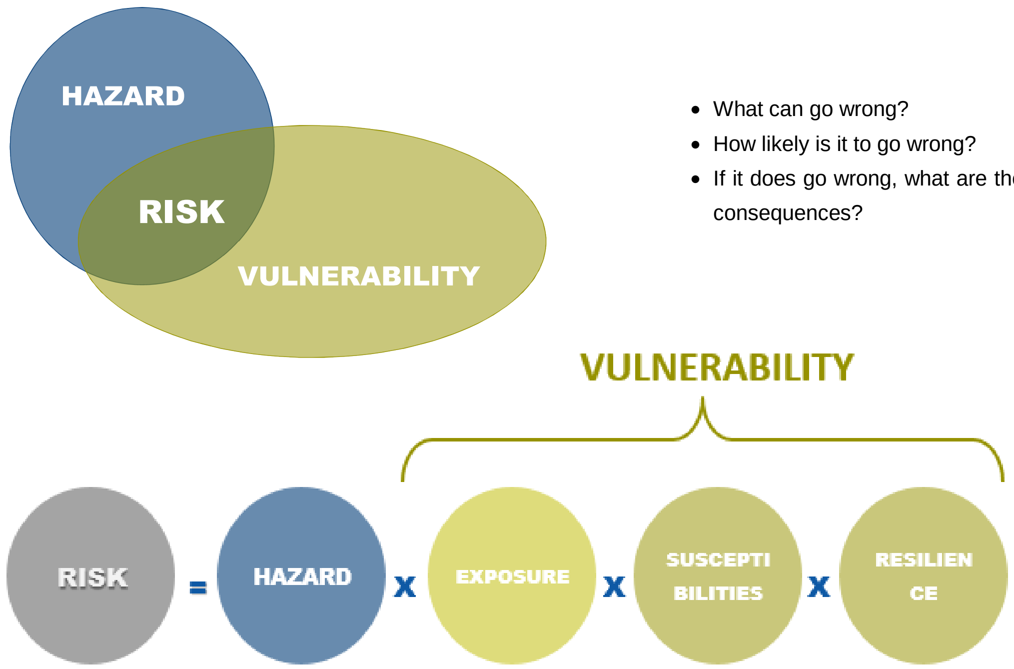
Figure 1.2: Summary of different sources of uncertainty and some of their contributing factors relating to hazard risk and climate change. Source: http://www.mfe.govt.nz/publications/climate-change/coastal-hazards-and-climate-change-guidance-manual-local-government-n-23

Risk is associated with the interaction between environmental phenomena, communities and the surrounding environment. Under ISO 31000:2009 the emphasis is on "**the effect**" rather than on "the event" (something happening). According to ISO 31000:2009, risk can be expressed in terms of a combination of the consequences of an event, or a change in circumstances, and the associated probability of occurrence, while in a more social based risk approach, the risk can be assessed through the combination of the hazard likelihood and the vulnerability of the system referring to the propensity of exposed elements to suffer adverse effects when impacted by hazard events (Figure 1.3).

Risk is only present if it represents harm to humans. Thus, to identify risks, it is necessary to take into account the **nature of the hazard** and the **factors** that affect the consequences (impacts).

As mentioned in the Deliverable 4.1, the extent of consequences are a complex function of the exposure, the susceptibilities of the elements exposed and the resilience of a system: *i)* the degree of exposure (measured by the number of the elements at risk or by their value), *ii)* the vulnerability of the system referring to the propensity of exposed elements to suffer adverse effects (damages) as a consequence of certain level or characteristic of the hazardous event (measured by the susceptibility of those elements to the risk, originated by their vulnerability) and on *iii)* the system resilience (coping and recovery capacity).

RISK (*r*) = Probability (*p*) x Consequences (*c*) or Hazard (H) x Vulnerability (V)



- What can go wrong?
- How likely is it to go wrong?
- If it does go wrong, what are the consequences?

Figure 1.3: In a social based risk approach, the risk can be assessed through the combination between the hazard likelihood and the vulnerability of the system refers to the propensity of exposed elements such as human beings, their livelihoods, and assets to suffer adverse effects when impacted by hazard events.

According to the BINGO glossary, the mentioned key could be expressed as following:

Hazard: as a source of potential harm. A hazard can be a risk source or a dangerous phenomenon that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage.

Vulnerability as the propensity of exposed elements (such as human beings, their livelihoods and assets) to suffer adverse effects when impacted by hazard events. Vulnerability is related to predisposition or capacities that favour, either adversely or beneficially, the adverse effects on the exposed elements. Vulnerability refers to exposure, susceptibility and resilience.

Exposure: considered as the predisposition of a system to be disrupted by a hazardous event (flood, drought, or other) due to its location in the same area of influence. Exposure can be also understood as the values that are present at the location where a hazardous event (floods, drought, etc.) can occur. These values can be tangible, as goods, infrastructure or mostly people, or intangible cultural heritage or image. The indicators for this component can be separated in two categories: 1) the first one covers the exposure of different elements at risk and the second ii) one give details on the general characteristics of the hazardous event.

Susceptibility: considered as the elements exposed within the system, which influence the probabilities of being harmed at times of hazardous event (due to their vulnerabilities). Susceptibility is related to system characteristics, including the social context of hazardous event damage formation. For floods, for instance, the physical vulnerabilities (infants, elderly, disabled) are related especially to the awareness and preparedness of affected people regarding the risk they live with (before the flood), the institutions that are involved in mitigating and reducing the effects of the hazards and the existence of possible measures, like evacuation routes to be used during the floods.

Resilience: considered as the capacity of a system to endure any perturbation, like floods, droughts or other hazardous phenomena, maintaining significant levels of efficiency in its social, economic, environmental and physical components. Resilience to hazardous event damages can be considered only in places with past events, since the main focus is on the experiences encountered during and after the events.

Impact or consequence: considered as the extent of harm, which can be expected under certain conditions of exposure, susceptibilities and resilience.

2 OVERVIEW OF BINGO RESEARCH SITES FOR RISK IDENTIFICATION

2.1. Hydro-meteorological hazards and socio economic sectors addressed

Natural hydro-meteorological hazards addressed

Water is the central resource in BINGO. Climate change is the driving force for adaptation. Deviations from average weather patterns can lead to extreme meteorological conditions. BINGO addresses mainly extreme conditions of precipitation and wind / atmospheric pressure giving rise to risks. These meteorological conditions have different hydrological manifestations of river flow, storage capacity (superficial or groundwater) and marine behaviour, giving rise to inundations (riverine, urban, estuarine) or droughts.

The extreme meteorological conditions (sources of hazard) are addressed in work package 2. Their repercussions in the natural water cycle or in the urban areas (hydrological manifestations) are addressed in work package 3. According to the way the research sites were set up in BINGO, the hydrologic repercussion of the meteorological conditions is, in fact, where the hazard (potential for harm) lies for humans (Figure 2.1).

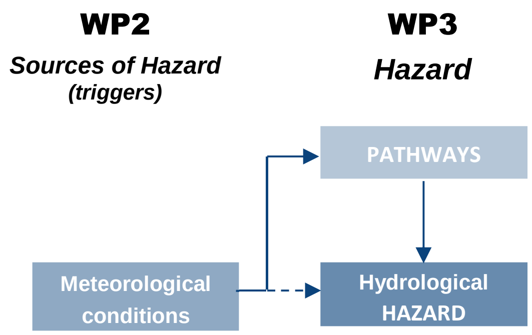


Figure 2.1: From hazard sources (meteorological conditions) to hazards (hydrologic repercussion)

In some BINGO case studies, the hydro-meteorological hazard is associated with other sources of hazard, as for example, oceanographic sources (sea level rise, spring tides) or domestic sewerage, resulting in combined sewer overflow (CSO). The complexity of the pathways linking the meteorological conditions to the existing hazards differs for each BINGO research site.

The **hydro-meteorological hazards** covered by the six BINGO research sites are:

- **Droughts**, associated with extreme dry periods;
- **Inundations** with inland origin, due to intensive precipitation episodes:
    - River floods;
    - Pluvial urban floods and combined sewerage overflow (CSO); and
- **Inundations** with marine origin (storm surges), due strong winds and low atmospheric pressure conditions.

Socio economic activities addressed

The main general **objectives of BINGO** are to provide adaptation strategies for the climate change-related challenges: sustainable use of resources; continuity and sustainability of services; strengthening key economic activities; safeguard public safety and protection of the environment.

Work package 4 (WP4) is responsible within the project for assessing the potential impacts of the extreme hydro-meteorological conditions on people or on socio-economic water related activities (elements at risk) and for assessing the potential consequences on the objectives established for the risk management processes in Task 4.1, for each research site (

Figure 2.2).

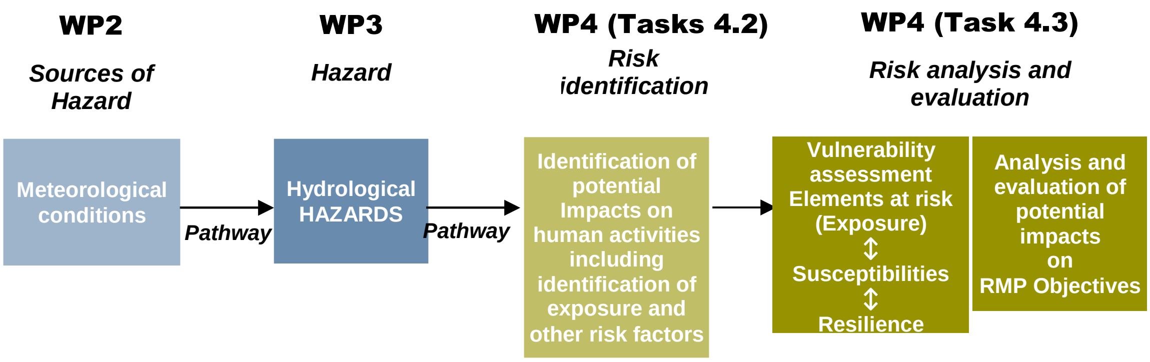


Figure 2.2: BINGO work packages aligned with risk identification steps (adapted from 31000:2009)

Deliverable D4.1 has fully identified the public, or economic, water related sectoral activities addressed per type of natural hazardous event considered (Rocha *et al.* 2017). They are the following:

- Water resources management (DE and NL);
- Urban drainage management (NO and SP);

- Public water supply (PT, CY, NL and NO);
- Agriculture water supply (PT and CY).
- People and property safety (PT and CY).

Table 2.1 identifies the sectoral activities addressed in each research site per type of natural hazardous event, as well as the water related issues concerning the activities/ sectors analysed. For general overview purposes of what this WP is addressing a brief reference to each research site concerns and its adaptation objectives in BINGO is provided.

Table 2.1: Public or economic sectors addressed per type of hydro-meteorological hazard at each research site

HYDRO METEOROL. Hazard		SECTOR / ACTIVITY addressed			Geographical Area	Water related ISSUE
LOW Precipitation / DROUGHTS	●	DE	WATER RESOURCES MANAGEMENT		Wupper river basin	Water Availability
	●	NL	WATER RESOURCES MANAGEMENT		The Veluwe	Water Availability
	●	PT		AGRICULTURE	Tagus: Sorraia Valley (VS)	Water Availability
					Tagus: Lezíria Grande Vila Franca de Xira (LGVFX)	Irrigation Water Availability & Quality (Salinity)
					Tagus: Lezíria do Vale do Tejo (LVT)	Water resources governance
	●	CY		AGRICULTURE	Peristerona Watershed	Irrigation Water Availability
	●	PT		PUBLIC WATER SUPPLY	Tagus	Water Availability & Quality
	●	CY		PUBLIC WATER SUPPLY	Peristerona Watershed	Water Availability
	●	NL		PUBLIC WATER SUPPLY	The Veluwe	Water Availability
	●	NO		PUBLIC WATER SUPPLY	Reservoirs intakes to Bergen	Water Availability
HIGH Precipitation / FLOODS	●	DE	WATER RESOURCES MANAGEMENT		Wupper river basin	Inundations
	●	NO	URBAN DRAINAGE MANAGEMENT		Damsgaard Area	Urban inundations
	●	SP	URBAN DRAINAGE MANAGEMENT		Badalona	Urban inundations Sea water quality
	●	PT		People and property safety	Trancão	Urban Inundations
	●	CY		People and property safety	Pedieos Watershed	Urban Inundations
STORM S. SEA Rise	●	PT		AGRICULTURE	Tagus: Lezíria Grande Vila Franca de Xira (LGVFX)	Agricultural lands Inundations

Wupper, Germany

A mid-size river catchment, the Wupper river basin has an area of **813 km²**. It is a strongly industrialized region, ranging over several municipalities, with a population of **950.000 people**.

Wupper Association (WA) has the responsibility for water management within the catchment area. It operates an extensive multipurpose system, including twelve reservoirs, eleven wastewater treatment plants, numerous stormwater tanks and flood control reservoirs. It is a public body that performs its tasks in a wide range of water uses: water supply provision, wastewater treatment, flood protection, together within the maintenance and ecological development of the rivers and streams, and has a wide range of associated members: town councils, local and district authorities, municipal water suppliers, effluent disposal businesses, and trade and industrial organizations.

Risk addressed problems: Flash floods increase, extreme dry periods, ecological impacts and availability of water for different uses. *Management of Wupper water resources* to face both types of extreme weather events is the central adaptation issue in BINGO.

The Veluwe, Netherlands

Veluwe aquifers and streams function as water source for **1.250 km^2** of reserve area, which ranges over several municipalities and serves as an important area for nature and recreation. Around 80% of the Veluwe area is covered by natural vegetation. The system has up to 20 or 30 small stream valleys and springs and is totally dependent on **groundwater**. Subsoil contains a large reservoir of fresh groundwater that is exploited for the production of drinking water for the consumption needs of **two million people**.

Risk addressed problems: Climate projections anticipate precipitation shifts from summer to winter and an increase in potential evapotranspiration during summers, meaning that dry spells will occur more frequently and intensively. As a consequence, the importance of the Veluwe for drinking water production will increase. This last together with the increasing need for fresh water for agriculture, recreation and groundwater dependent habitats and aquatic life in small streams and the overall management of natural vegetation at the Veluwe can lead to conflicts. *Management of the Veluwe groundwater* and adaptation of *Public water supply utility (Vitens)* under climate change is the adaptation purpose in BINGO.

Troodos, Cyprus

The Cyprus research site is located along the northern steep slopes of the Troodos Mountains in Cyprus, which form the "water tower" of the island. The northern slopes are in the rain shadow of the mountains and are less endowed with water resources than the southern slopes. **A small river basin catchment**, Peristerona watershed presents a drainage area of **112 km^2**, with agriculture as the most relevant economic activity in the region. The Peristerona Watershed's communities covered 3.273 ha in 2010. The local population in the communities is approximately **5.000 inhabitants.** Domestic water supply is managed by the local community councils, and is exclusively based on **groundwater**. Another small catchment, **Pedieos Watershed** (120 km^2) is prone to flash floods in urban areas.

Risk addressed problems: the northern slopes of the Troodos have potential for being affected by climate change, impacting the southern slopes. The main objective in **Peristerona Watershed** is to develop adaptation strategies to sustain the two main water uses in dry years: <u>*agriculture and domestic water supply*</u>, and to identify the <u>*flash flood hazard*</u> in the urban areas of **Pedieos**.

Tagus, Portugal

The Portuguese research site is located in the lower Tagus river basin, a **large international river catchment**, with an area of 80.600 km^2 and different land uses. Climate change adaptation is focused on two key sectors, one concerning public water supply and the other concerning agriculture, one of the most relevant economic activities in the region. Inundations due to flash floods or storm surges are also a concern.

The **public water supply utility** addressed in BINGO is EPAL that supplies the almost 3 million people of Lisbon city and surrounding 35 municipalities of the right margin of the river Tagus. EPAL doesn't hold private water sources and is dependent of surface and groundwater resources shared with other users. Water resources governance dependence is a key issue for EPAL.

The **agriculture sector** in BINGO is focused on two different realities, public irrigation perimeters of the left lower margin of Tagus river (Sorraia Valley - 15365 ha and Lezíria Grande de Vila Franca de Xira - 13420 ha), with irrigation infrastructures funded by the government, the former holding storage capacity and the latter no, and the remaining region of Lezíria do Vale do Tejo, where intensive irrigate agriculture is practiced, but irrigation infrastructures are private. Water resources governance practices affect the three sites differently.

The Trancão river basin, covering an area of 279 km^2, is a small basin heavily industrialized and densely populated. Its downstream urban area is prone to flash floods due to land use changes and high population density.

Risk addressed problems: Reduction in water availability and quality degradation, associated with more frequent and intense droughts, are the main concerns of the agriculture and public water supply (EPAL) sectors. The main *agriculture adaptation* objectives in BINGO are to strengthen the economic agriculture sector by developing strategies for climate change adaptation in the region under low precipitation events and to identify the risk associated with salty inundation due to spring tides combined with storms surges and sea level rise scenarios. *Public water supply (EPAL)* addresses essentially water resources competition, and how its governance affects the accomplishment of its objectives of raw water production. Water resources governance is a crossing issue between both sectors. *Flash flood hazard* to people safety and property in Trancão urban areas is also analysed.

Bergen, Norway

Bergen is enclosed between high mountains and the open sea. Situated on the west coast, Bergen is Norway's second largest city, with a population of about **270.000** inhabitants. Two main issues have been selected for this research site:

i) The **Damsgård area**, with a catchment of around **8.3 km², ** has an **urban drainage** system facing problems during intense precipitation events that are becoming more frequent due to climate change. Stormwater discharge, combined sewer overflow (CSO) and consequent pollution to receiving waters (the Puddefjord) are of the highest concern in the city of Bergen.

(ii) to identify the risk of water availability under drought conditions for **public water supply to Bergen**. Water sources provide from a set of reservoirs, namely, Jordalsvannet (**9.7** km^2), Svartediket (**12.3** km^2), Sædalen (**1.9** km^2) and Espeland (**9** km^2), all located in **small watersheds**.

Risk addressed problems: Due to previous periods of water shortage there is a concern about the capacity of *supplying Bergen with drinking water during droughts*. The existing risk will be estimated.

Being exposed to heavy precipitation loads, *flash floods* and storm water related challenges and the subsequent impacts on the wastewater and stormwater systems and recipients, the **urban drainage** system impacting the Damsgård area will be the focus of attention.

Badalona, Spain

Badalona with more than **215.000 inhabitants** within its administrative limits on a land area of more than **21.2 km^2**, is situated on the left bank of the Besòs River facing the Mediterranean Sea. Seven natural ephemeral watercourses**,** coming from the upper part of city (from the mountain to the sea) have been channelled below the urbanized area. One of the most valued resource and one of the main sources of income in Badalona is tourism, based on its beaches, which stretch along nearly 5 km, with an average width of approximately 55 m and about 187.000 m^2 of sand. This space is occupied by 1.3 millions of visitors per year. **Urban drainage** in Badalona has a special relevance due to the climate and morphological characteristics of its catchments. Badalona´s drainage network is mainly a combined system with 318 km of sewers.

Risk addressed problems: The high demographic density and land imperviousness exacerbate urban *flood risk* and *CSO affects negatively coastal water quality* during intensive rainy events.

2.2. Objectives of the RMP at the six research sites

The categories of risks to be addressed were already selected in Task 4.1, and expressed into scopes and specific objectives.

Figure 2.3 and Figure 2.4 summarize the main scopes of the risk management processes at each research site per type of hydrologic hazard, drought or inundations, developed in Task 4.1 and presented in Deliverable 4.1 (Rocha *et al.*, 2017). They include mainly: continuity of the service; environmental protection; financial; image and reputation; people safeguard and property protection. To fulfil those scopes, specific objectives were also defined.

The aim of Task 4.2 is to identify, for the selected hydro-meteorological hazards, what endanger the achievement of those specific objectives.

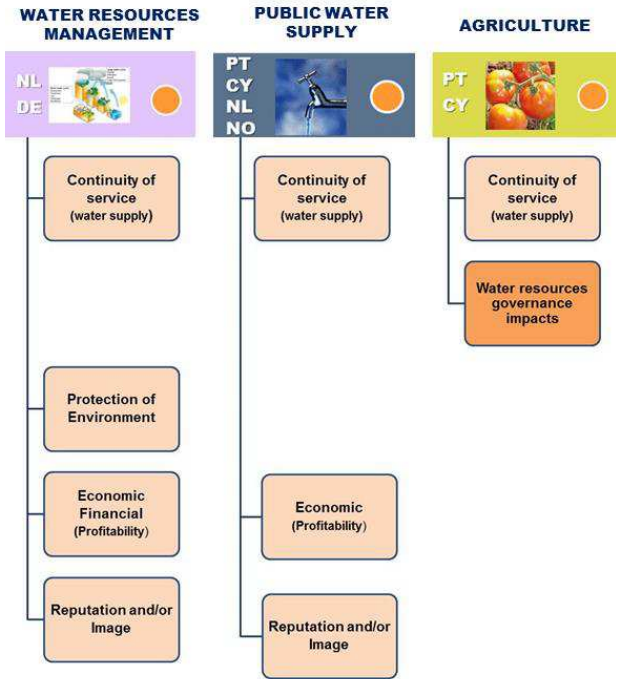


Figure 2.3: Droughts: Scopes of the RMP at each research site

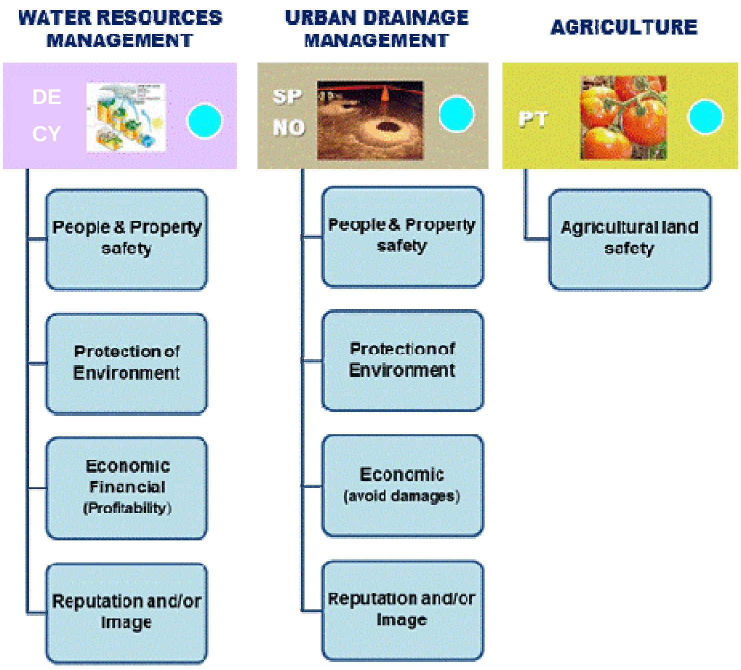


Figure 2.4: Inundations: Scopes of the RMP at each research site

3 GUIDELINES FOR RISK IDENTIFICATION FOR BINGO RMP

3.1. Risk identification process overview

Risk identification (ISO Guide 73:2009) is a process that involves **finding, recognizing, and describing the risks** that could affect the achievement of an organization's **objectives**. It is the process of identifying possible sources of risk, areas of impact, events, their causes (or sets of circumstances) and their potential consequences. An event can be a change in circumstances with potential to affect the achievement of objectives. The aim of risk identification is to generate a comprehensive list of risks based on those events that might create, enhance, prevent, degrade, accelerate or delay the achievement of objectives.

In a free risk identification exercise, there are two main ways to identify risk:

- Identifying *retrospective risks*: Retrospective risks are those that have previously occurred, such as incidents or accidents[1]. Retrospective risk identification is the most common and the easiest way to identify risk. It is easier to believe something if it has happened before and it is easier to quantify its impact and to see the damage it has caused.
- Identifying *prospective risks*: Prospective risks are often harder to identify. These are things that have not yet happened, but might happen sometime in the future. Identification should include all risks, whether or not they are currently being managed. The rationale here is to record all significant risks and monitor or review the effectiveness of their control.

Risk identification is usually a two steps process. It involves ***Step 1*** focus on a general, but very useful, identification approach, the identification of *risk sources* (sources of hazard, associated with the environmental hazardous phenomena and sources of exposure, associated with human elements exposed) and on *risk factors* (factors that can affect final outcome of consequences and make a system vulnerable). Risk identification also involves ***Step 2*** designing possible events (facts happening), from their causes (set of risk sources), impact on socioeconomic activities, till their final

[1] An event can sometimes be referred to as an "incident" or "accident".
An event without consequences can also be referred to as a "near miss", "incident", "near hit" or "close call".
An **accident** is a bad event caused by error or by chance. Accidents are always unintentional, and they usually result in some damage or injury.
All accidents can also be described as incidents, but not all incidents are accidents. Accident definition is often similar to incident, but supports the mindset that it *could not have been prevented.*

consequences on the risk management objectives of an entity. Step 2 is the basis for risk analysis.

A previous step is often due. **Step zero** of risk identification deals with retrospective risks. It is based in the systematization of knowledge about past events, the hazard profile, which is a written description of the set of risks under analysis. This process describes the causes and characteristics of each hazard; how it has effectuated in the past; and, what elements were impacted: geographical area with impacted population, infrastructure, and environment that have historically been vulnerable to each specific hazard. Profiling hazard events includes the documentation of the history, causes and characteristics of the hazard in the impacted geographical areas.

3.2. Decision on risk identification extent in BINGO and on methodological approach

Risk identification is generally based on a three steps approach – from Step 0 to Step 2. As further showed, the outcomes of the different risk identification steps have different purposes and different possible follow ups.

At this point of BINGO development, the categories of risks to be addressed were already selected in Task 4.1 and in deliverable D4.1 (Rocha *et. al.* 2017). They include risks to: continuity of the service; environmental protection; financial; image and reputation; people safeguard and property protection objectives (emphasis on “the effect” rather than on “the event”). Risk identification will identify sources and factors of risk potentially compromising the achievement of those objectives.

Before proceeding from risk identification to other BINGO tasks, it is useful to remind that alternative liaisons exist between risk identification steps and risk treatment, to be performed in Task 5.3 (WP5), although with different in-depth levels (Table 3.1.). Step 0 and step 1 allow to proceed directly to WP5, jumping Task 4.3. Therefore, at this point of BINGO development, teams needed to decide the approach to pursue in their case studies.

In fact, risk identification needs to be adapted to each BINGO research site according to its goals within the project and to the risk management process established in Task 4.1. Risk framework implementation is a process of continuous adaptation within the project. As new information or deeper knowledge is being obtained, re-evaluation of some previous decisions may be justified. According and as already stated, this was a moment to decide upon risk identification extent for each case study of each research site, because it has influence: i) in the approach to pursue for risk treatment; ii) on the steps and techniques to perform risk identification and ii) on risk assessment achievement. Highlights on links between risk identification in BINGO (WP4.2) and risk treatment (WP5) are presented in Table 3.1.

Table 3.1: Links in BINGO between risk identification (WP 4.2) and risk treatment (WP5)

WP4 - Task 4.2 ***Risk Identification***	**WP2 and WP3** **(*Risk sources and Hazard Results*)**	**WP4 - Task 4.3** ***Risk Analysis Risk Evaluation***	**WP5** ***Risk Treatment (CC Adaptation)***
Step 0 ***Hazard profile***	Not necessary	Not possible	**→ POSSIBLE with limitations** No further knowledge then before BINGO about existing risks (hazard and impact on human activities). Quite useful to support Task 5.3 before obtaining WP2 & WP3 final simulations
Step 1 ***Identification of relevant hazards, risk sources and risk factors (Exposure, susceptibility and resilience of the system)***	Necessary only to a certain extent, as means to identify the hazard sources pathway and, in some cases, the elements at risk (exposed elements)	Not possible	**→ POSSIBLE with limitations** Identification of the risk factors are equivalent of identification of the aspects upon which are possible to perform risk treatment, for each hazard. Associated level of risk is not known nor is a prioritization of factors possible.
Step 2 ***Explore scenarios and potential events***	Indispensable for event probability assessment, and, in some cases, for identification of elements at risk (exposed elements)	Possible Can be a very delicate or sensitive procedure, with strong social and political impact	**→ POSSIBLE in all extent** Allows full risk treatment and setting of a strategy supported by a risk assessment framework, as risks and risk factors (*susceptibility and resilience of the system*) can be prioritized (depending on set of events designed).

Also important is the selection of a **technique or methodological approach** to perform effective risk identification. This must consider: i) The type of risk and the nature of the socioeconomic activity addressed; ii) If risk analysis and risk evaluation are going to be performed. If that is the case, methodologies need to be compatible, order to assure that risk assessment can be achieved.

Qualitative, semi-quantitative and quantitative methods, as well as or a combination of these, can be used for risk analysis and risk evaluation, depending on the circumstances, as referred in ISO 31010:2009. Examples of common risk identification methods are presented in the guidelines (Rocha, 2017).

3.3. Step 0: Building the hazard profile

Step zero is based on the hazard profile (knowledge about past events) and has, as main added value to BINGO, the systematization of information about the causes and characteristics of each hazard and their consequences in past events. It provides no new information. Relevant past risk events were identified in Task 3.1 and in deliverable D3.1 (Beek, T. aus der, *et. al.* 2016).

Due to BINGO chronogram, hazard profile can be quite helpful to support Task 5.3 development, till final climate change scenarios predictions from WP2 and respective hydrological pathways form WP3 are achieved. Each research site team should decide if hazard profile presented is enough to perform the following tasks or if some further detailing should be developed.

3.4. Step 1: Identifying relevant hazards, risk sources and risk factors

3.4.1 Step 1 overview

Step 1 focuses, for each hazard, on the *identification of risk factors* (factors that can affect the final extent of consequences, either by affecting the probability or magnitude of the hazard, or by affecting the vulnerabilities of the system), identifies the aspects upon which it is possible to perform risk treatment (climate change adaptation in BINGO).

It is a general, but very useful approach, allowing jumping directly to risk treatment, if necessary, in spite of existing relevant limitations, summarised in Table 3.1. Recourse to WP2 and WP3 may or may not be necessary in this step.

Step 1 of risk identification ends after the identification of the elements (assets or receptors) exposed to the hazard and their vulnerabilities (Figure 3.1). The assessment of the inherent susceptibilities to the hazard and the potential extent of consequences is part of risk analysis (Task 4.3).

Step 1 is about identifying relevant hazards, risk sources and risk factors.

- Risk **sources (threats; opportunities)**: Sources refer to element which alone or in combination has the intrinsic potential to give rise to risk. It is where the hazardous event is potentially originated. A risk source can be tangible or intangible.
- Relevant **hazards** identification (causes or sets of circumstances of the events). Examples of water related potentially hazardous natural phenomena are:

  - Atmospheric or meteorological: tropical storms; atmospheric pressure changes; etc.
  - Hydro-meteorological: river flooding; storm surges; drought; salinization; erosion and sedimentation, etc.

- Risk factor is something that can have an effect on the risk level, meaning that can affect consequences or likelihood of the event. It is related with vulnerability components like exposure, susceptibility and capacity to recovery of a system. Examples: infrastructures conditions; human physical intrinsic sensitivity; social and economic vulnerabilities, preparedness, etc.

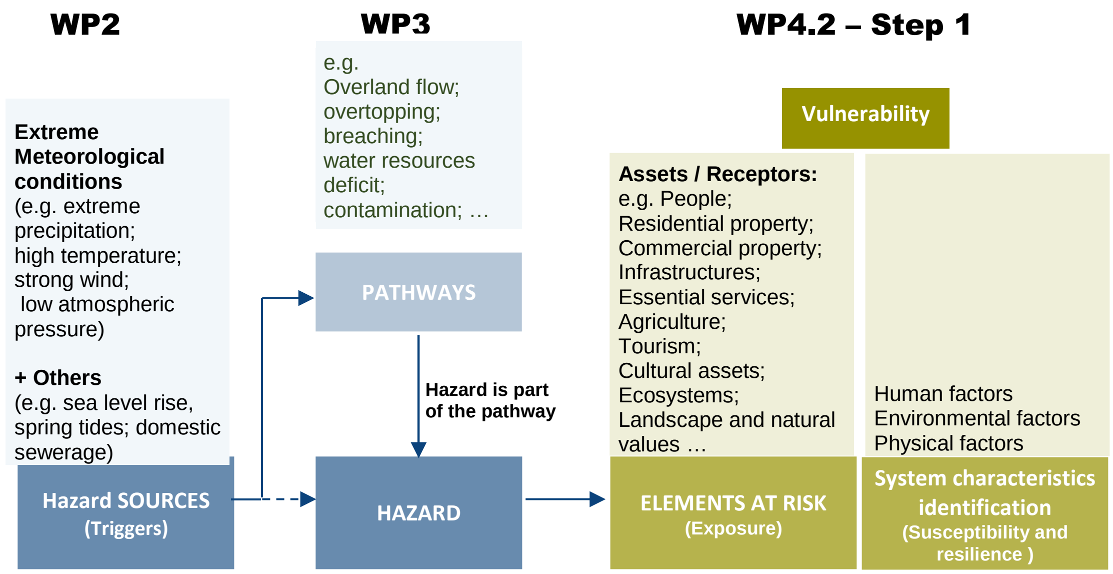


Figure 3.1: Step 1 of risk identification. Examples of relevant hazards, risk sources and risk factors for BINGO research sites

Figure 3.2 illustrates the relation between risk sources and factors leading to a hazard and a risk, if exposure occurs.

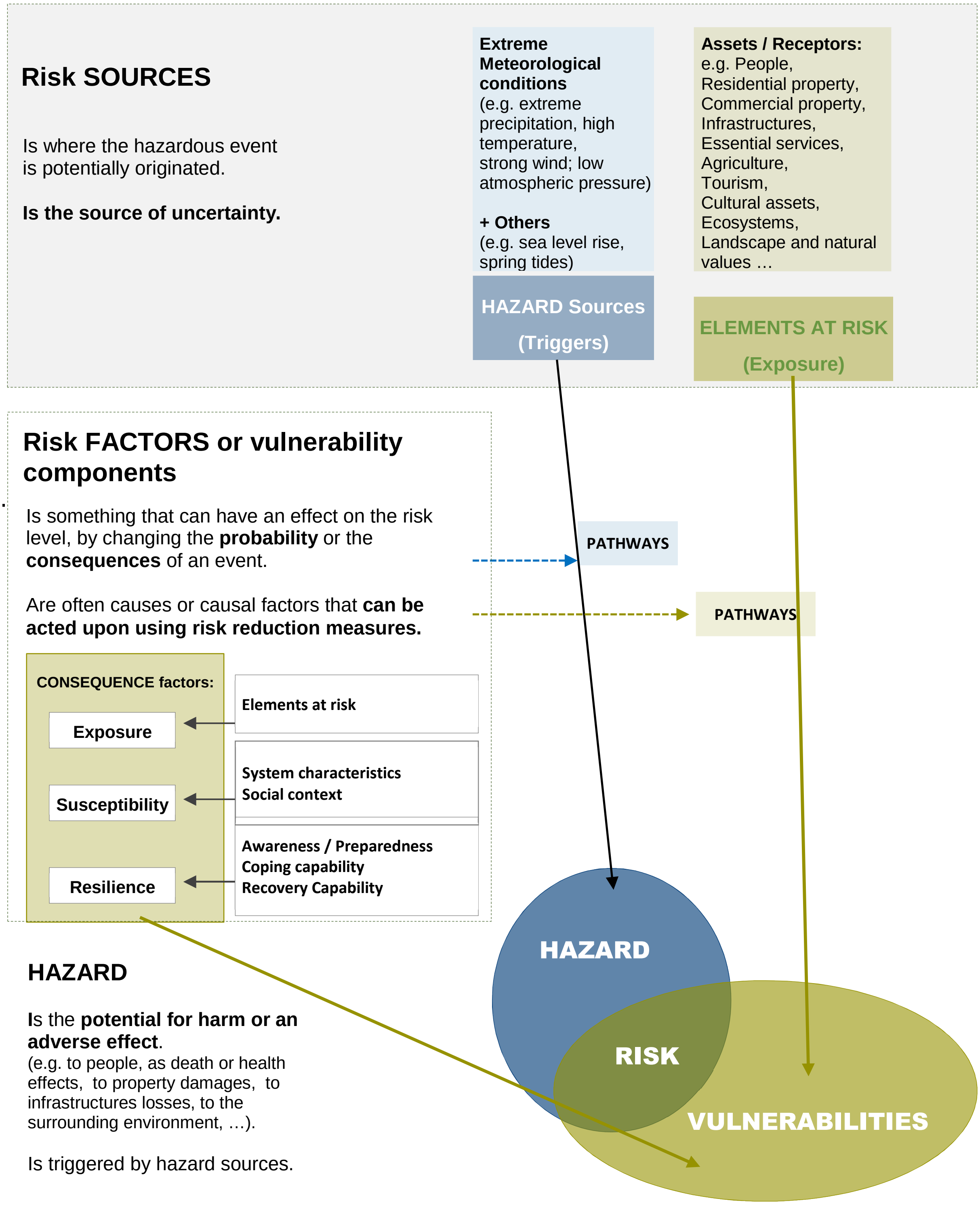


Figure 3.2: Step 1 of risk identification. Identification of relevant hazards, risk sources and risk factors

3.4.2 Risk sources

Risk sources (threats; opportunities) are where the hazardous event potentially begins or is originated. Sources refer to elements which alone or in combination have the intrinsic potential to give rise to risk. A risk source can be tangible (e.g. extreme precipitation episode) or intangible (e.g. legislation alteration, political changes). They are the sources of uncertainty.

Risk addresses the effect of uncertainty on the achievement of the objectives of an organization (risk owner), *effect* being a deviation from the expected, either positive and/or negative. Therefore, risk sources are threats and opportunities, or sources of losses or gains. BINGO is more focused on negative effects, hence, from now on, risk identification tips will only address negative impacts. However, in some cases, positive impacts may be considered.

The interpretation of the definition of risk source can vary. Some consider that risk sources can be external or internal to the system. Other consider that threats are (external) risk sources in the same way as weaknesses are (internal) risk sources (the same applies for opportunities and strengths), meaning that internal risk sources are more associated with risk factors. Some agree with this latter opinion stating that external risk sources are beyond the control of the organization, while internal risk sources are under the control of the organization. It is a mere question of terminology. What really matters is to recognise that **risk sources can include the threats** (sometimes also the hazards) **and the elements exposed**. Exposure of assets and receptor could be included in the risk source, but also it can be considered as a vulnerability component (Figure 3.2). Also, that identification should include risks whether or not their source is under the control of the organization, even though the risk source or cause may not be evident (ISO 31000:2009).

The "Guidelines for risk identification" (Rocha, 2017) provided some tips for risk sources identification in BINGO research sites.

3.4.3 Hazard

Hazard is the source for potential harm or an adverse effect (for example, to people as health effects, to organizations as property or equipment losses, or to the environment). In BINGO, the harm comes from the hydrological manifestations of the meteorological phenomena, rather than from the meteorological phenomena themselves. These hydrological manifestations refer to river flows, to storage capacities (superficial or groundwater) and to storm surges, giving rise to inundations (riverine, urban, estuarine) or to droughts.

The main sources of hazard (extreme meteorological conditions) are addressed in WP2. Their hydrological manifestations in the natural water cycle (river urban areas and in the estuaries) are addressed in WP3.

Hydrological hazard definition and assessment is part of the hazard pathway. Which level of the hazard pathway should be considered as the real hazard, with potential to cause the harm for humans, depends on the risk management objectives. As an example, it is referred that in flooding cases addressed in BINGO, the potential for harm does not rely on the river flow itself but in the overland flow, being the hazard harmful characteristics the water level, runoff velocity, water density (destruction capacity), water contamination, etc. The pathway from the source to the potential for harm needs to be understood. WP3 may identify the pathways between the meteorological sources of hazard and their hydrologic manifestation, but in some cases do not identify the potential for harm itself (water level in flooded areas, runoff velocity, etc.).

For drought it is important to bear in mind that hazard can be natural but also man induced. This is the case, for example, of the supply systems addressed in BINGO due to the demand and the water resources imbalance induced (either for public or agricultural supply or other purposes) (PT, CY, NL). Risk in supply systems is directly related to water shortage, which differs from hydrological drought because it is related to a water shortage to satisfy demands. The shortage results from an unbalance between the water resources available for supply and the demand. It can be originated by a meteorological phenomenon, but is also conditioned by other time-varying factors, such as demand development, supply infrastructures and management strategies. The result of the unbalance is a supply deficit to satisfy demand.

According to the different components of the natural hydrologic cycle or human activities affected by a drought event, it is possible to distinguish among: meteorological, agricultural, hydrological drought or operational drought (supply systems drought) (Iglesias *et al*., 2007; Rocha, 2017).

Table 3.2 puts in evidence the conceptual difference between drought and man-induced water shortage or water scarcity.

Organizing the risks by the source of the problem greatly facilitates allocation of responsibility (either before or after the event).

Table 3.2: Concepts related to water availability (Adapted from Iglesias A. *et al*., 2007)

	Nature produced	Man induced
Temporary	**Drought** Natural causal (random) temporary condition of consistent reduction in precipitation of water availability with respect to the normal values, spanning along a significant period of time and covering a wide region. It results from persistent lower-than-average precipitation.	**Water shortage** Man-induced temporary water imbalance. Water shortage in a water supply system represents a water deficit with respect to the demand, which can occur due to a drought or other anthropic causes (e.g. low water quality, ill services).
Permanent	**Aridity** Natural permanent climatic condition with very low average annual or seasonal precipitation.	**Water scarcity** Indicates a permanent condition of unbalance between water resources and water demands in a region characterized by an arid climate and/or a fast increasing of water demand, associated to growth of population, extension of irrigated agriculture, etc. **Desertification:** The degradation of land in arid, semi-arid and other areas with a dry season; caused primarily by over-exploitation and inappropriate land use interacting with climatic variance.

3.4.4 Risk factors or vulnerability components

The hazard only becomes a risk if it can cause damage, harm or adverse effects to individuals, goods or to organizations (the receptors, or assets). Without human presence the hazard gives no rise to risk. The severity of a disaster depends on both the physical nature of the extreme event and the social nature of the human populations and communities affected by the event.

Risk sources are associated with the hazard origin while ***risk factors*** **(**or **vulnerability components)** are related with the **susceptibilities of the system**, its **resilience** or its **exposure** to the hazard**.** They are all contributing to the risk. In this framework, vulnerability is the socio-economic dimension of disasters.

Risk factor / vulnerability component is something that can have an effect on the risk level, **by changing the probability or the consequences** of an event. **Risk factors** are often causes or causal factors that **can be acted upon using risk reduction measures**. **Risk factors** typically cover three main categories of elements exposed, namely: **human** factors; **environmental** factors; and **physical** factors. Vulnerability of human elements result of the range of economic, social, cultural, institutional, political and psychological factors that shape people's lives and the environment that they live in (Twigg, 2004).

In the vulnerability definition of ISO 31000:2009 (intrinsic properties of something resulting in susceptibility to a risk source that can lead to an event with a consequence), exposure of an element is separated from vulnerability of the system (Figure 3.2), since it is possible to be exposed and, at the same time, not susceptible to the hazard. In the BINGO framework (Rocha et al., 2017), vulnerability refers to exposure, but also to the intrinsic characteristics of an individual, a group or an organization and, finally, its capacity to anticipate, cope with (preparedness), resist and recover (resilience) from the impact of a hazardous event.

Risk factors / vulnerability components identifications aims to identify underlying causes of risk, meaning the characteristics of the exposed elements that **modify the level of risk** derived from inadequate structures, management, and technology, or caused by economic, environmental, and social factors.

Risk factors identify the vulnerabilities that can be acted upon using risk reduction measures. Distinction among categories of risk factors is relevant to identify if it is really possible to act upon them (it is not often possible to act on some environmental factors) and to identify the responsible(s) for action. Risk factor identification is an important step to perform Task 5.3 (WP5). Vulnerability also concerns the wider environmental and social conditions that limit people and communities to cope with the impact of hazard (Birkmann, 2006), but this may be beyond BINGO comprehensive scopes.

Risk factors / vulnerability components are assigned to the elements exposed (assets or receptors) or to components of the asset. The external and internal contexts developed in Task 4.1 (deliverable D4.1) should help to identify some of the existing vulnerabilities. Some examples of risk factors are presented in the “Guidelines for risk identification” (Rocha, 2017).

3.5. Step 2: Identifying causes, events and consequences

3.5.1 Step 2 overview

Step 2 designs possible events (facts happening), from their causes (set of risk sources), impact on socioeconomic activities, till their final consequences on the risk management objectives. The events designed in this step will be the events subjected to risk analysis (assessment of the probability of the event occurrence and magnitude of their consequences).

In WP2 different meteorological events can be selected. WP3 predicts their possible pathways in the water cycle, identifying the hazard(s) generated. WP3 allows designing plausible events.

Step 2 is about exploring **scenarios** and potential **events**

When a hazardous threat actually happens and harms humans, it is an event (Figure 3.3). In this step one must explore scenarios and potential **events** (occurrence or change of a particular set of circumstances), their causes and consequences:

- **Causes** are opportunities, threats and sometimes the hazards. Causes are the sources of risk (ISO, 2009b). They can be internal or external to the system. A cause is a potential trigger that may result in the risk event occurring. A single risk event may have a specific cause or multiple possible causes. A single cause may be applicable to multiple risks. Each cause corresponds to a risk source identified in step 1 or a combination of risk sources;
- An **event** (occurrence or change of a particular set of circumstances) can be one or more occurrences, and can have several causes (ISO, 2009a). Exploring events is a means to find possible causes of risk and adverse consequences. Consequences were not yet considered in the first step (hazard and sources and factors of risk identification);
- **Consequence (or impact)** is the outcome of an event affecting objectives (ISO, 2009a).

Figure 3.3: Step 2 of risk identification. Events design

The aim of this step is to generate a comprehensive list of risks based on events that might create, enhance, prevent, degrade, accelerate or delay the achievement of objectives set in Task 4.1. Besides identifying what might happen, it is necessary to consider possible causes and scenarios that show what consequences can occur (why and how). All significant causes and consequences should be considered (ISO, 2009b).

This step is especially relevant to support risk analysis, as it can be performed based on *events* (or *scenarios*) set up in step 2 of risk identification. It enables to assess the extent of consequences and the likelihood of the events and, hence, the level of risk.

Step 1 was an identification process, where impacts on elements exposed to the hazard were not explicitly addressed. No concrete situations were set in place. Step 2 moves forward, setting scenes that, by allowing later assessment (risk analysis and evaluation), enable prioritization of risks or assets at risk.

This step intends to identify why and how can it happen. This is accomplished by:

- Setting events (facts), and
- Identifying their causes (combination of hazard sources) and potential consequences (impacts on elements exposed and then consequences over the objectives of the risk management process).

Figure 3.4 summarises the steps involved in step 2 of risk identification based on events.

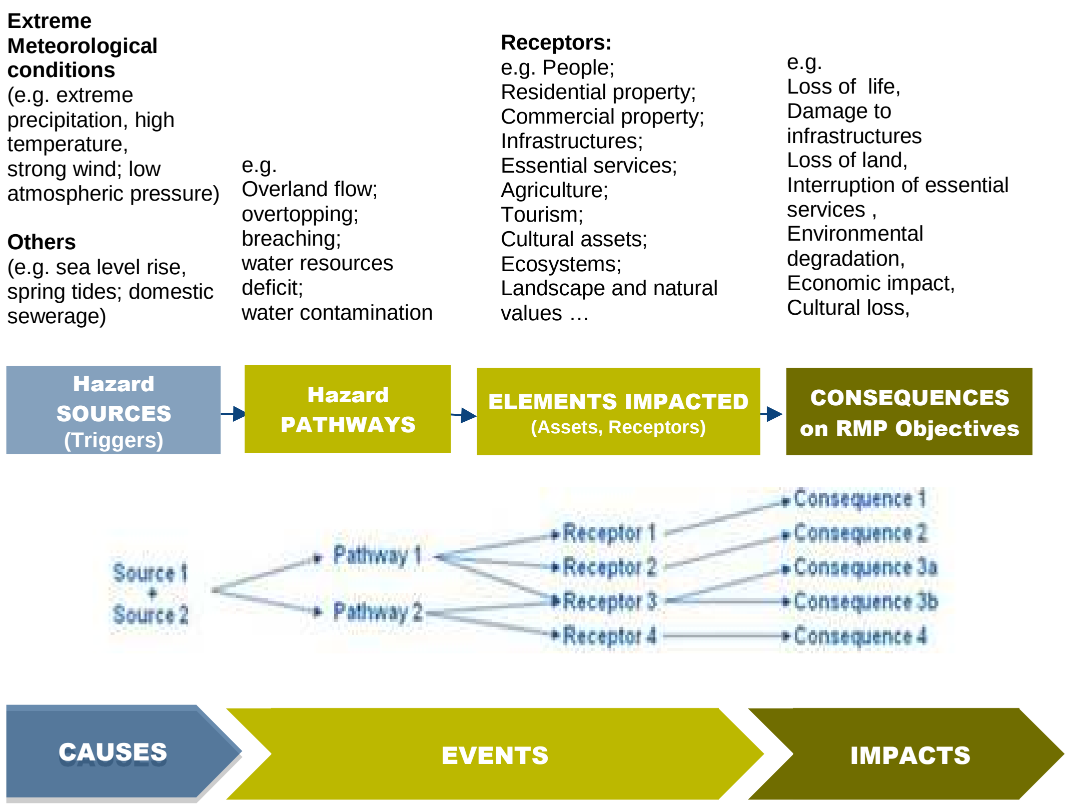


Figure 3.4: Step 2 of risk identification. Setting events

3.5.2 *Causes*

Identifying causes is the process of identifying the potential triggers that may result in the risk event occurring. A single risk event designed may have one specific cause or multiple possible causes. A single cause may be applicable to multiple risks. The causes can be external or internal to the system.

The hazard sources considered so far in BINGO are meteorological conditions, oceanographic conditions and domestic sewerage. If a risk source considered relevant was not considered in step 1, it should be included in step 2. Extreme meteorological conditions are forecasted in work package 2, and a probability of occurrence can be associated to each meteorological episode selected.

Cause(s) is one of the risk sources identified in step 1 or a specific combination of several of those risk sources. Examples: i) extreme meteorological conditions of strong wind and low pressure (source 1) combined with a spring tide (source 2); ii) extreme intensive precipitation combined with domestic sewerage producing combined sewer overflows during summer time; iii) extreme low precipitation during two consecutive years combined with increase in water demand.

3.5.3 Events

When selecting events take into consideration the following:

- An event is only a risk if there is a degree of uncertainty associated with it;
- A natural hazard is a threat (or source) of a naturally occurring event only if it will have a negative effect on humans (usually called a natural disaster);
- An event comprehends the natural hazard pathway and the human "pathway" or elements impacted (assets, receptors or resources exposed). The hazardous event is part of the event pathway. Its effects on assets are also part of the pathway, or event description. When describing an event refer to both.
- An event can have a combination of sources and have multiple consequences.

The hazardous event is part of the event pathway. However, it may be easy to associate a probability of occurrence to a set of meteorological conditions triggering the event but it may not be equally easy to associate a probability to its hydrological manifestation, due to a set of circumstances. In step 2 of risk identification, assess the likelihood it is not an issue, but as this step serves as the basis for risk analysis, attention should be paid to this matter (

Figure 3.5).

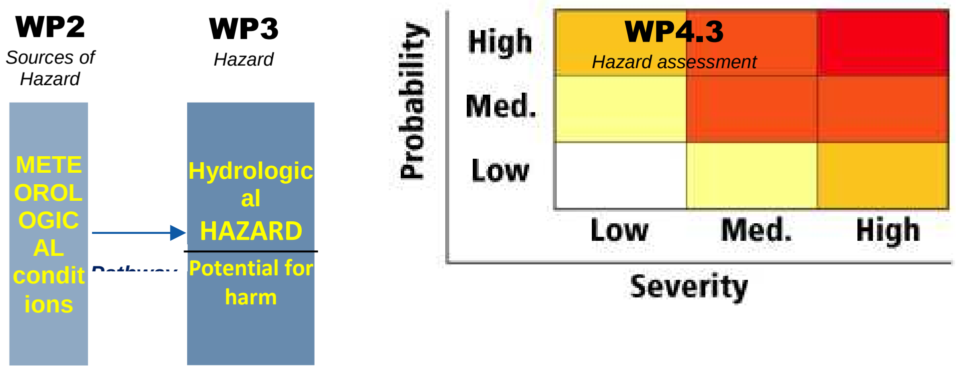


Figure 3.5: Hazard assessment linking events to Task 4.3

3.5.4 Consequences

An event can lead to a range of consequences. A consequence can be certain or uncertain and can have positive or negative effects on objectives. Consequences can be expressed qualitatively or quantitatively. As BINGO is focused on negative impacts, opportunities and positive effects are not extensively pursued.

A hazard source can trigger a serious of the knock-on effects of particular consequences, including cascade and cumulative effects (pathway). Hydrological manifestation is an example of a primary effect of the meteorological precipitation phenomena. Hazardous process of all types can have primary, secondary and tertiary effects. Risk identification should/ could include examination of the knock-on effects:

- *Primary* effects occur as a result of the process itself. For example overland flow during a flood, or water deterioration during a drought;
- *Secondary* effects occur only because a primary effect has caused them. For example, disruption of water service as a result of a flood or as a result of insufficient water resources for supply during a drought; contamination resulting from forest fires triggered by dry weather and temperature rise;
- *Tertiary effects* are long-term effects that are set off as a result of a primary event. These include things like loss of habitat caused by a flood, desertification caused by a long drought, etc.

As previously referred, in risk identification process, consequences and vulnerability components (or risk factors) are identified but not assessed in severity. Later, in risk analysis vulnerability and consequences can be expressed qualitatively or quantitatively, and in terms of direct or indirect economic, social, environmental or other impacts. Therefore, in step 2 is still useful to notice the following:

- A wide range of consequences should be considered even if the risk source or cause may not be evident. Consider possible causes and scenarios that show what consequences can occur. All significant causes and consequences should be considered;
- Set a sufficient number of events in order to allow risk analysis and risk evaluation (prioritizing risks, etc.) (Figure 3.6).

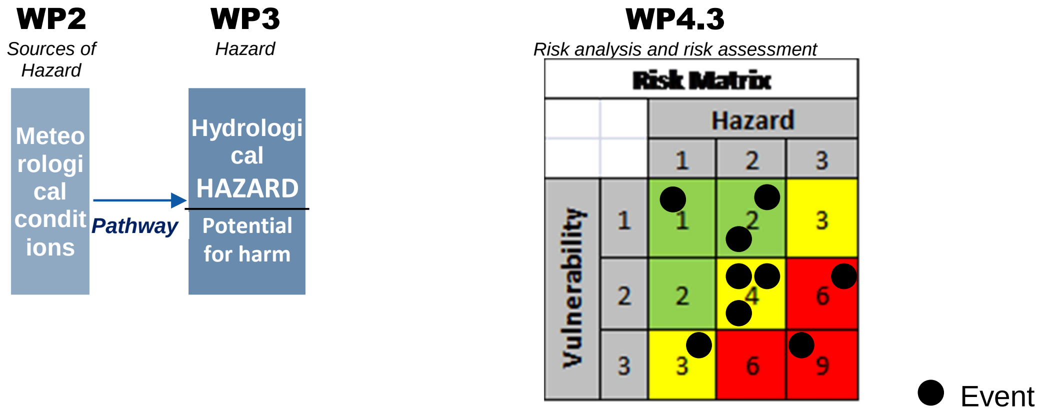


Figure 3.6: Linking events to Task 4.3

3.6. Preparing next WP4 tasks

After events design in step 2 risk identification, it is possible to proceed easily to risk analysis based on these events (Figure 3.7). Task 4.3 is an assessment phase, developing a systematic analysis of several contributing and leading factors (e.g. extent of the exposure, multiple exposures, and intrinsic characteristics of the population or systems being assessed, such as their recovery capacity) resulting in: 1) hazard assessments of the likelihood of adverse events, and 2) assessments of consequences (i.e. their impact).

Risk analysis requires a point of view. This point of view was identified in Task 4.1 (risk owner). The evaluation of the magnitude of consequences, to assess the risk, is based on the indicators established in Task 4.1 for the risk criteria. Then, for grading the level of risk in risk evaluation (e.g. high, moderate, low), it is necessary to have established the acceptance levels of risk criteria. This task should have been accomplished in the context (Task 4.1), but it was not possible in some research sites. It needs to be established prior to Task 4.3 developing.

This has been the right moment for teams to review the context (Task 4.1) and decide if the point of view identified really corresponded to the approach desired for their case studies. It also necessary to review the indicators selected in risk criteria to assess the extent of consequences as they could require too much information or information not available. The objective was to achieve a satisfactory risk assessment in the next Bingo WP4 task.

As a summary, Figure 3.8 illustrates the significance of all steps involved in risk assessment aligned with risk concept.

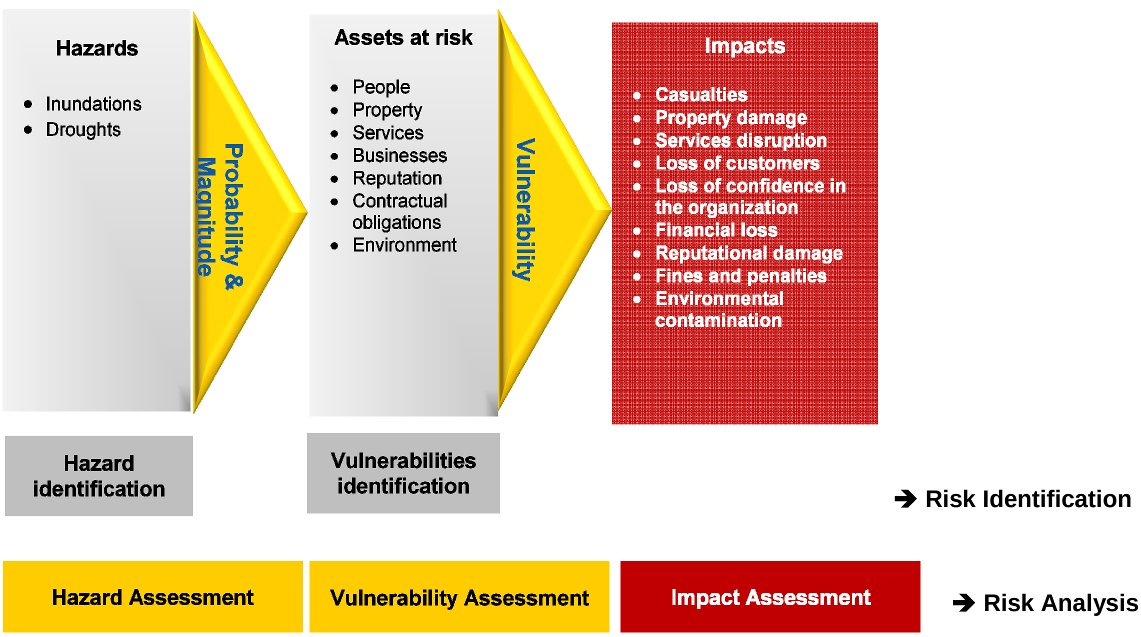


Figure 3.7: From risk identification to risk assessment (Adapted from https://www.ready.gov/risk-assessment)

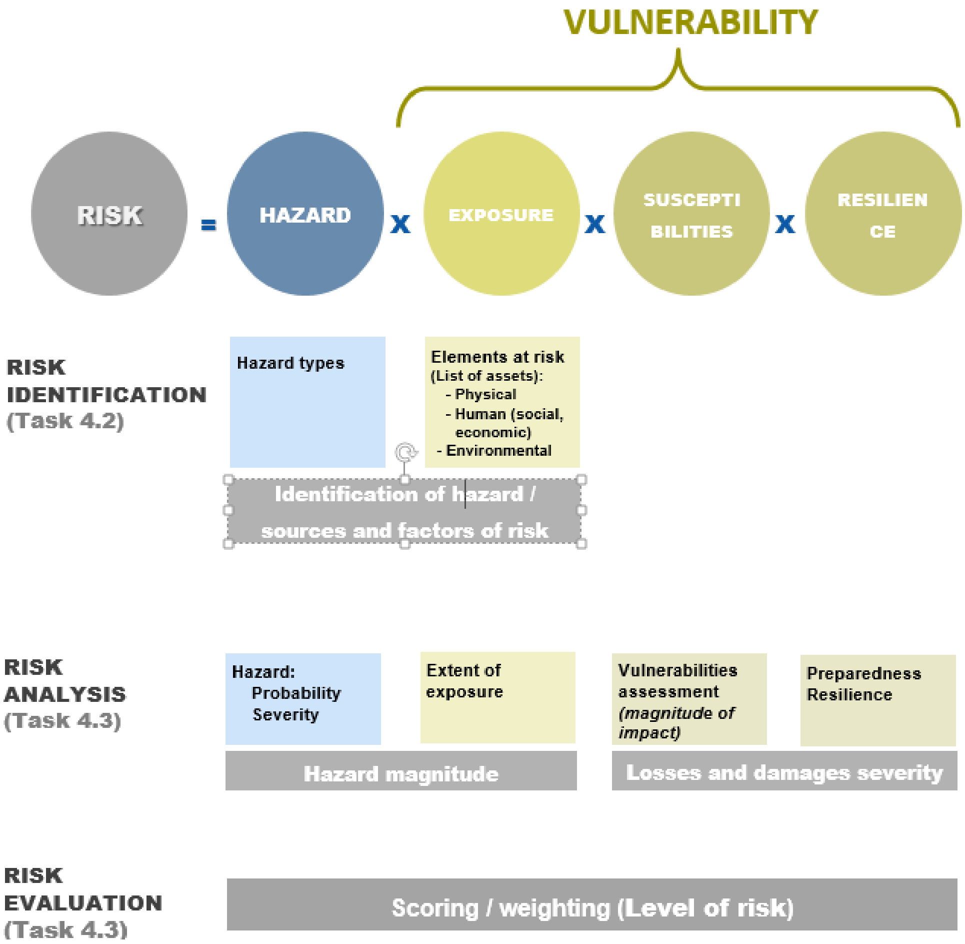


Figure 3.8: **Significance of steps involved in risk assessment aligned with risk definition**

4 RISK IDENTIFICATION AT WUPPERVERBAND RESEARCH SITE

4.1. Brief research site introduction

The German Research Site is the Wupper basin. The Wupper basin has an area of 813 km² and a population of ca. 950,000 inhabitants, ranging over several municipalities. Altogether 900 small rivers and brooks longer than 500 m are located in the basin, see Figure 4.1. A detailed system characterization and a description of water use and related problems can be found in Deliverable 4.1 (Rocha et al. 2017) and 3.1 (Beek et al. 2016).

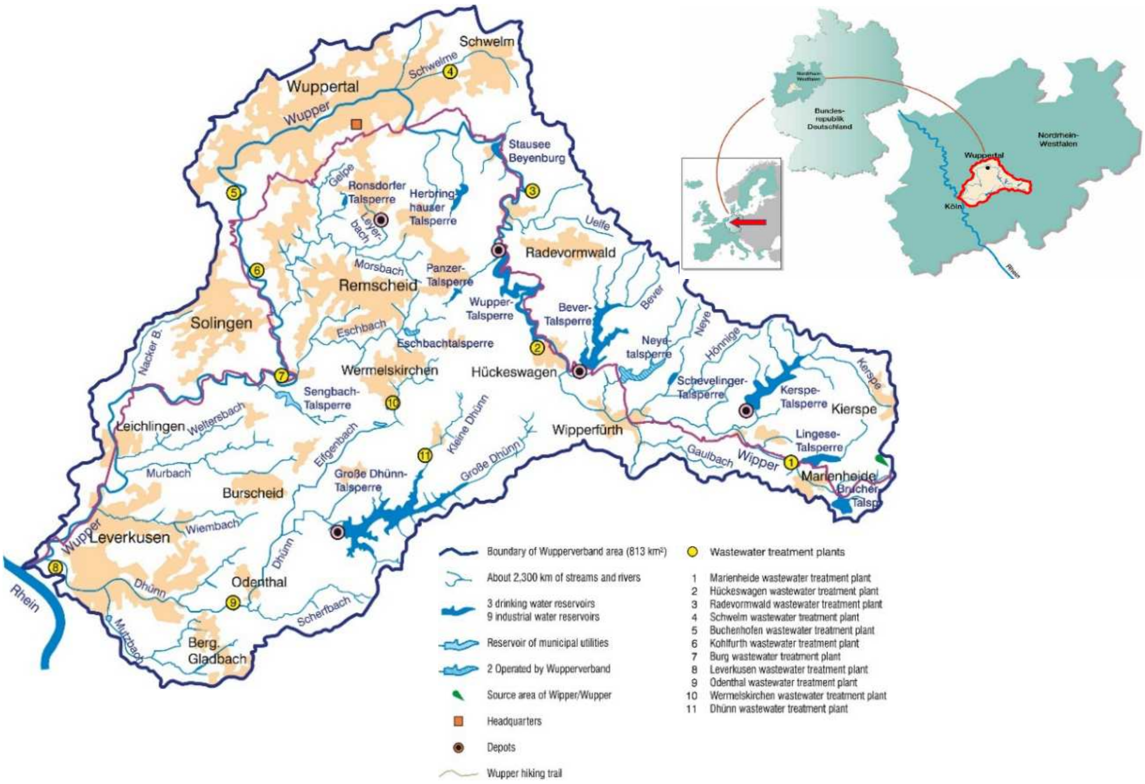


Figure 4.1: Wupper River Basin (Rocha et al. 2017, p. 70)

The main water use categories within the Wupper River Basin are summarized as follows: raw water (as sum of domestic water and process or industrial water) and service water (water used for reservoir and flood management as well as ecological flow regulation, e. g. reservoir storage); in this case, service water corresponds to the direct withdrawal from the Wupper River. Domestic water is used for indoor and outdoor household purposes (including raw water provision for drinking water treatment, which is under the responsibility of five drinking water utilities) as well as for small businesses. Process or industrial water is utilized e.g., for “cooling purposes” at power plants. Reservoirs for raw water supply (including drinking water) are: Große Dhünn, Eschbach, Kerspe, Neye, Herbringhauser, and Sengbach reservoirs. Alone the Große Dhünn Reservoir - the second largest drinking water reservoir in Germany - supplies drinking water for ca. 500,000 people, serving also as emergency water supplier for the city of Düsseldorf. Table 4.1 shows the supplied municipalities and population that benefit from the six raw water supply reservoirs. The overall water demand - for raw water and service water - for the year 2015 was ca. 231.49 Mm³/year.

Table 4.1: Supplied municipalities from the Große Dhünn, Eschbach, Kerspe, Neye, Herbringhauser, and Sengbach reservoirs (raw water, incl. drinking water)

Municipality (Gemeinde)	District (Kreis)	Gov. district (Reg.-Bez)	Municipality total population (in 2015)
Burscheid	Rheinisch-Bergischer Kreis	Cologne	18.064
Hückeswagen	Oberbergischer Kreis	Cologne	15.039
Remscheid	Kreisfreie Stadt	Düsseldorf	108.370
Wermelskirchen	Rheinisch-Bergischer Kreis	Cologne	34.297
Odenthal	Rheinisch-Bergischer Kreis	Cologne	14.688
Leichlingen	Rheinisch-Bergischer Kreis	Cologne	27.485
Wuppertal	Kreisfreie Stadt	Düsseldorf	344.421
Leverkusen	Kreisfreie Stadt	Cologne	161.713
Radevormwald	Oberbergischer Kreis	Cologne	21.908
Solingen	Kreisfreie Stadt	Düsseldorf	156.182
		Total	**902.107**

Mean annual precipitation is relatively constant with respect to the weather normal distribution. Mean monthly precipitation during the 20th century shows a shift of the rainy season from spring (April) to summer (June/July) having a negative impact for the water quality and quantity within the reservoirs, see also D3.1 (Beek et al. 2017, pp.27-28).

Weather extremes have been well known in the last decades for the Wupper basin, see also D3.1 (Beek et al. 2016, pp. 26-27). Ranging from dry periods in spring time (important for filling the reservoirs) to heavy convective rainfalls (flash floods) in summer time and the combination of snow melting and rainfall during the winter season (causing river floods). Heavy recent floods have been recorded for 2007, 2011, and 2013, for both winter and summer seasons.

4.2. Water resources management under droughts

With regard to water management and water provision during low precipitation events the following objectives for the risk management process of Wupper Research Site can be summarized:

1. Service water for reservoir management and ecological flow regulation.
2. Raw water provision to members/customers according to contracts (water supply, industry), hydropower generation and other purposes (e. g. agriculture and leisure activities).

4.2.1 Scopes and objectives of the RMP

1. The risk scope in the Wupper Association research site include: people and property safety, service continuity, protection of environment, maintenance of good reputation and image, economic (external to WA), financial (WA). **Provision of service water** (reservoir management and ecological flow regulation)

The Wupper Association has to provide reservoir management to ensure a minimum flow necessary to preserve individual species and river´s ecosystem in the rivers of WA´s catchment area. Water availability and reservoir management may be affected by CC, nevertheless, WA has to ensure the ecological flow and is therefore the risk owner to guarantee the ecological flow. The objective within BINGO is the management of the risk to miss the target of sufficient water flow (i.e. water quantity) due to CC.

2. Provision of raw water

a. Raw water provision – drinking water

WA provides raw water for drinking water treatment and has to deal with water quantity and quality issues, which may be affected by CC. WA is not finally responsible for the provision of drinking water, but is responsible for the provision of raw water in a sufficient amount to the drinking water suppliers. Contracts with water supply companies exist concerning the provision of the needed raw water quantity. Quality aspects are not contractually regulated. WA is therefore the risk owner for raw water quantity. The objective within BINGO is the management of the risk to miss the target for provision of contractually fixed raw water quantity due to CC.

b. Provision of process water - water for industrial use

WA provides water used for industrial purposes (production, cooling or hydropower generation) which is taken from rivers by industrial companies. WA is committed by contracts to ensure a sufficient water flow for the industrial members. This comprises also a sufficient water flow for cooling purposes. Therefore, WA is the risk owner for the provision of sufficient water for industrial use. The objective within BINGO is the management of the risk to miss the targets for water quantity for industrial use due to CC.

c. Provision of process water - hydropower

WA operates own hydropower plants. Even if there is no fixed limit of hydropower to be supplied to external customers, WA has the aim to produce as much hydropower as possible and to reduce the import of electricity from other companies. The objective within BINGO is the management of this task in combination with other tasks for water quantity management due to CC.

The scopes and objectives of the risk assessment process for the WA are also listed in Table 4.2.

Table 4.2: Wupper River Basin RS – Objectives and scopes of the risk assessment processes of the Wupper Association

<table>
<tr><th rowspan="2">RISK OWNER</th><th rowspan="2">OBJECTIVES</th><th rowspan="2">SCOPES</th><th rowspan="2">SPECIFIC OBJECTIVES</th><th colspan="3">Risk Assesment extent</th><th colspan="2">Risk Treatment</th></tr>
<tr><th>Identification</th><th>Analysis</th><th>Evaluation</th><th>Site specific</th><th>GOVERNANCE</th></tr>
<tr><td rowspan="4">WUPPER ASSOCIATION</td><td rowspan="4">PROVISION OF ENOUGH WATER,
during low precipitation events, for:
- members/ customers according to contracts (water supply, industry);
- own hydropower generation;
- environment (ecological flow)</td><td>Service continuity of water provision for members/customers according to contracts:
- drinking water treatment utilities
- industries</td><td>Assure sufficient volumes of water supply during 365 days/year for drinking water treatment and industrial costumers</td><td rowspan="4">✓</td><td rowspan="4">✓</td><td rowspan="4">✓</td><td rowspan="4">YES</td><td rowspan="4">Water resource governance</td></tr>
<tr><td>Protection of the environment</td><td>Assure ecological flow in duration and quantity</td></tr>
<tr><td>Maintenance of good Reputation and Image</td><td>Needs and expectations satisfied</td></tr>
<tr><td>Financial</td><td>Production of hydropower,</td></tr>
</table>

RISK OWNER	OBJECTIVES	SCOPES	SPECIFIC OBJECTIVES	Risk Assesment extent			Risk Treatment	
				Identification	Analysis	Evaluation	Site specific	GOVERNANCE
			avoid WA financial losses					

4.2.2 Hazards, risk sources and risk factors

Potential hazards within WA catchment area in periods with insufficient rainfall or droughts, accordingly risk sources and risk factors affecting the likelihood or consequences of hazard identified are summarized in Table 4.3.

Table 4.3: Hazard, hazard sources and, risk factors and elements at risk under drought periods within the Wupper catchment

Risk Category			HAZARD	HAZARD		CONSEQUENCES	
RISK OWNER	**SCOPES**	**SPECIFIC OBJECTIVES**		**HAZARD source(s)**	**Risk FACTORS** Affecting Hazard likelihood	**ELEMENTS at risk (Exposure)**	**Risk FACTORS** Affecting Consequences
Wupper Association	**Service continuity** of water provision for members/customers according to contracts: - drinking water treatment utilities - industries	Assure sufficient volumes of water supply during 365 days/year for drinking water treatment and industrial costumers	Water resources scarcity (raw water shortage)	- changes in average annual rainfall or reduced rainfall - increased temperature (air & water) with higher extreme temperatures and/or higher temperatures in general - increased evaporation rates (due to higher temperature)	temperature (water and air), water use/demand, customer structure, water height and velocity, kind of plantation, shadowing of soil and water body, soil type, sealed ground, building density, reservoir level	1. Essential Services - industrial customers (provision of process water for cooling systems) - drinking water utilities (provision of raw water) 2. Financial Impact (WA) (process water for hydropower generation)	temperature (water and air), water use/demand, customer structure, sealed ground, building density
	Financial	Production of hydropower, avoid WA financial losses					
	Maintenance of **good Reputation** and **Image**	Needs and expectations satisfied	Water resources scarcity (service water shortage)	- changes in average annual rainfall or reduced rainfall - increased temperature (air & water) with higher extreme temperatures and/or higher temperatures in general - increased evaporation rates (due to higher temperature)	temperature (water and air), water use/demand, customer structure, water height and velocity, kind of plantation, shadowing of soil and water body, soil type, sealed ground, building density, reservoir level	Ecosystems (ecological flow)	temperature (water and air), water quality, water height and velocity, water use/demand, sealed ground
	Protection of the **environment**	Assure ecological flow in duration and quantity					

4.2.3 Events

Events which may occur within WA catchment area in periods with insufficient rainfall or droughts and their corresponding causes and consequences on RMP objectives are summarized in Table 4.4.

Table 4.4: Events design for the Wupper catchment – drought periods

EVENTS			
EVENT description		CAUSES	CONSEQUENCES
HAZARD pathways	ELEMENTS Impacted	(set of Hazard Sources)	(on RMP objectives)
Water resources (raw water and service water) deficit within the Wupper catchment area	**Essential services** - industrial customers of WA (provision of process water for cooling systems) - drinking water utilities (provison of raw water); **Probability** WA (Financial): hydropower generation; **Ecosystems and Landscape** (ecological flow)	Water shortage (service and raw water) due to - low precipitation during an extended period; - land use (increased sealed ground, lower soil satisfaction) - increase in water demand	- Interruption of essential services; - economic/financial loss: • due to unprovided raw water, • due to unprovided hydropower supply, • on water supply entities or industrial companies caused by substitution of missing raw water; - environmental degradation

4.3. Water resources management during flooding periods

With regard to water management/flood protection during heavy rainfall events/flooding, the following objectives for the RMP of Wupper Research Site will be taken into account:

- Flood protection for infrastructure, public and private property, health and life according to principle goals of WA (i. e. management of surface water level, protection against floods for different return periods)

4.3.1 Scopes and objectives of the RMP

The risk scope related to flood management in the Wupper Association research site include: people and property safety, service continuity, protection of environment, maintenance of good reputation and image, economic (external to WA), financial (WA). In Table the objectives and scopes of the RM process of the WA are listed.

The risk of flooding of infrastructure like roads, houses, industrial area may be increased by CC. The protection against floods is generally the duty of the owners of infrastructure. Nevertheless, one of the main goals of WA is the protection of infrastructure and people against floods and to avoid or to reduce the risk of damages, even if no contractual or legal commitments exist. Therefore, WA regards itself as risk owner for flood protection. The objective within BINGO is the management of the risk to miss the targets for surface water level due to CC.

Table 4.5: Wupper River Basin RS – Objectives and scopes of the risk assessment processes of the Wupper Association during flooding periods

RISK OWNER	OBJECTIVES	SCOPES	SPECIFIC OBJECTIVES	Risk Assesment extent			Risk Treatment	
				Identification	Analysis	Evaluation	Site specific	GOVERNANCE
WUPPER ASSOCIATION	**MANAGE WATER RESOURCES for protection of goods and property protection and safeguard of population** (Management of surface water level, protection against floods for different annualities (depending on catchment and possibilities) Keeping of legal requirements concerning treatment of waste/stormwater)	Protection of **environment**	Keeping of legal requirements concerning treatment of waste/storm water	✓	✓	✓	YES	Water resource governance
		People and **property safety**	Management of surface water level, protection against floods for different annualities (depending on catchment and possibilities)					
		Reputation and **image**	Needs and expectations satisfied					
		Economic (External to WA)	Avoid financial losses external to WA					
		Financial (WA)	Avoid WA financial losses					

4.3.2 *Hazards, risk sources and risk factors*

Potential hazards within WA catchment area in periods of high precipitation or flooding, accordingly risk sources and risk factors affecting the likelihood or consequences of hazard identified are summarized in Table 4.6.

Table 4.6: Hazard, hazard sources, risk factors and elements at risk under periods of high precipitation or flooding within the Wupper catchment

HAZARD	HAZARD		CONSEQUENCES	
	HAZARD source(s)	**Risk FACTORS** Affecting Hazard likelihood	**ELEMENTS at risk (Exposure)**	**Risk FACTORS** Affecting Consequences
Fluvial flooding	heavy rainfall events increased river flow from receiving water bodies, increased run-off from surfaces	Sealed ground, water uptake and storage capacity, water height and velocity	People, residential and commercial properties, infrastructures	Sealed ground, building density and kind of buildings

4.3.3 Events

Events which may occur within WA catchment area in periods of high precipitation or flooding and their corresponding causes and consequences on RMP objectives are summarized in Table 4.7.

Table 4.7: Events design for the Wupper catchment under periods of high precipitation or flooding

EVENTS			
EVENT description		**CAUSES**	**CONSEQUENCES**
HAZARD pathways	**ELEMENTS Impacted**	(set of Hazard Sources)	**(on RMP objectives)**
Fluvial flooding, strong velocity runoff, overland flooding	People, ecosystems, residential and commercial properties, infrastructures	- heavy rainfall event - landuse (increased sealed ground)	Injury, death; Damage to infrastructures Loss of land, Economic impact

4.4. Summary and remarks

Weather extremes have been well known in the last decades for the Wupper basin. Ranging from dry periods in spring time (important for filling the reservoirs) to heavy convective rainfalls in summer time and the combination of snow melting and rainfall during the winter season (causing river floods). Within the RMP of the Wupper catchment, two main events in terms of

- water provision (i. e. raw water and service water) in drought periods and
- fluvial flooding in heavy rain fall events will be determined.

Besides impacts derived from climate change, also other drivers (such as water demand in drought periods) or land use in terms of sealed area will be taken into account as risk factors based on work carried out in WP3 (i.e. land use and water use scenarios, see also D3.2 by Iacovides et al. 2016).

5 RISK IDENTIFICATION AT THE VELUWE RESEARCH SITE

5.1. Brief research site introduction

The Veluwe has a long history of dealing with water and water related risks. Because of the increased elevation of the area, in a country that is mostly just above or below sea level, the Veluwe provided a safe area for the first agricultural communities in the Netherlands. The hills of the Veluwe provided a safety for the floods that would often rage the country. However, the lower edges of the Veluwe proved more suitable for agriculture, because of the fresh water supply from the Veluwe groundwater system.

The Veluwe has rich groundwater resources. The groundwater table is characterized by a large underground groundwater resource (a freshwater bubble), which feeds 20 to 30 small stream valleys and springs or brooks (man-made streams) that run downstream to the fringes of the Veluwe. The yearly input into the Veluwe water system is 350 – 550 million m^3, with a computed average of 1 mm a day and 456 million m^3 a year. Estimates of the base flow of these systems range from 30 to 50 million m^3. Altogether, 22 pumping stations with a total volume of 110 million m^3 regulate the Veluwe water system.

Nowadays, the Veluwe, and its excellent water resources, serve many different functions. As is mentioned in D4.1, it still is primary water source for agriculture, industry, forestry, recreation and since the beginning of the 21st century also one of the main drinking water sources for the region. These functions more or less compete for the same resources, making long term drought the primary and most complex challenge for the region.

5.2. Water Resources Management

5.2.1 Scopes and objectives of the RMP

The first risk owner at the Veluwe is the Provincial government of the Province of Gelderland. As shown inTable 5.1, the primary objective of the province is to ensure a sustainable management of groundwater resources under different climate scenarios and in different seasons. The scope of this objective is threefold:

First, water resources management needs to ensure sufficient supply of groundwater to the public water supply company (Vitens). Specifically, the province should aim for abstraction allowances that are sustainable in the long term.

Second, since the Veluwe is an important historic and natural site, water resource management should contribute to the improvement and the protection of the natural landscape and the cultural heritage of the area. It should more specifically be ensured that water management does have a minimal economic impact on regional tourism.

Third, many surface waters are dependent on the Veluwe groundwater system. Sufficient volume should be provided to maintain the brooks and streams. This can in part be done by meeting the objectives already explicated in Natura 2000 and ensuring ecological flow in the water streams in the region.

Table 5.1: Objectives and Scope for the Provincial Government of Gelderland

RISK OWNER	OBJECTIVES	SCOPES	SPECIFIC OBJECTIVES	Risk Assessment extent			Risk Treatment	
				Identification	Analysis	Evaluation	SITE SPECIFIC	GOVERNANCE
PROVINCIAL GOVERNEMENT	**Sustainable groundwater management** ***under different climate scenario's and seasons***	**Provide water resources** for public water supply (PWS)	Optimize the sustainable **level of allowances**	✓	✓	✓	YES	Water resources governance
		Protect and improve the natural landscape and cultural heritage qualities of the Veluwe through sustainable groundwater management	Minimize economic impact on regional tourism					
		Provide sufficient volumes of groundwater for the **maintenance of surface waters** (waterstreams)	Meet **Natura 2000 objectives**					
			Ensure **ecological flow** in water streams					

5.2.2 Hazards, risk sources and risk factors

As shown in Table 5.2, the primary hazard for water resources management is a shortage in water resources (operational drought), which equates the insufficient availability of sufficient quality groundwater resources for all uses. This source for this hazard can be a series of dry years (e.g. three) which may reduce groundwater levels and increase water demand in many different areas. Dry years will also be associated with increasing temperatures leading to all kinds of heat effects, such as increased growth of algae, longer growth seasons (which increase water demand), more demand for industrial cooling water and more demand for drinking water and water for recreational activities. Increasing temperatures may also cause more tourists to visit the area, putting more pressure on natural resources.

The likelihood of the hazard can increase because of soil degradation, increased pressure on land use and heat stress due to urbanization. The hazards puts all sectors and actors that are dependent on the Veluwe groundwater at risk, including water management (surface and groundwater), public water supply, agriculture, forestry, private land owners, nature management (ecology), recreation and tourism, households and industry. Deregulation and decentralization are important risk factors, because it can negatively affect monitoring efforts and lead to more illegal drainage or dumping. Privatizations can also undermine the provincial monitoring and enforcement efforts. Finally, underground activities, for instance caused by sustainable heating systems, can affect the quality of groundwater resources.

Table 5.2: Hazards, risk sources and risk factors affecting the Provincial Government of Gelderland

Risk Category			HAZARD	HAZARD		CONSEQUENCES	
RISK OWNER	SCOPES	SPECIFIC OBJECTIVES	HAZARD	HAZARD source(s)	Risk FACTORS Affecting Hazard likelihood	ELEMENTS at risk (Exposure)	Risk FACTORS Affecting Consequences
PROVINCIONAL GOVERMENT OF GELDERLAND	**Provide water resources** for public water supply (PWS)	Optimize the sustainable **level of allowances**	Water resources shortage (operational drought) = insufficient availability of sufficient quality groundwater resources for all public and private uses	Long-term drought (e.g., a series of three dry years), which: a) may reduce groundwater levels and recharge, b) increases the demand for fresh water in the PWS sector to combat salinisation of drinking water resources, c) increases the demand for fresh water in the agricultural sector for irrigation, d) increases the demand for fresh water in nature management to combat low stream flow and sustain ecological values in these waters, e) reduces the availability and quality of groundwater resources in other parts of the Netherlands, increasing the demand on the Veluwe's groundwater resources. Warming and heat stress, which: • increases the growth of algae and bacteria, affecting quality of surface water and the water systems dependent on that (streams, springs, recreational water). • in natural and rural areas, increases evaporation while extending the growth season, which increases the demand for water in the agricultural and nature management sectors. • in urbanized environments, increasing	– Soil degradation due to unsustainable land-use and agricultural practices, affecting the quality of the soil and groundwater system. – Increased pressure on land-use for urbanization and tourism, reinforcing soil and nature degradation. – Urbanization (tourism infrastructure), leading to more heat stress.	All sectors and actors dependent upon the Veluwe's groundwater system, including: - Water management (surface and groundwater) - Public water supply - Agriculture - Forestry - Private land owners - Nature management (ecology) - Recreation and tourism - Households - Industry	– Deregulation and decentralisation, especially when it affects current monitoring and enforcement practices; it could increase (illegal) drainage or dumping activities but also lead to uncontrolled private abstractions, e.g. for gardening. – Privatization, which decreases provincial monitoring and enforcement capacities. – A growth in demand for sustainable energy, increasing underground construction activities which may affect groundwater quality.
	Protect and improve the natural, landscape and cultural heritage qualities of the Veluwe through sustainable groundwater management	Minimize economic impact on regional tourism					
		Meet **Natura 2000 objectives**					

Risk Category			HAZARD	HAZARD		CONSEQUENCES	
RISK OWNER	SCOPES	SPECIFIC OBJECTIVES		HAZARD source(s)	Risk FACTORS Affecting Hazard likelihood	ELEMENTS at risk (Exposure)	Risk FACTORS Affecting Consequences
	Provide sufficient volumes of groundwater for the **maintainance of surface waters** (waterstreams)	Ensure **ecological flow** in water streams		the demand for drinking water and (public and private) recreational water facilities. • increases the demand for industrial cooling water. • increases the attractiveness of the Veluwe as a recreational area and the water demand from the tourism sector accordingly.			

5.3. Public Water Supply

5.3.1 Scopes and objectives of the RMP

Table 5.3 shows the objectives and scopes for Vitens, the public water supply company for large parts of the east and north of The Netherlands. The main objective is to ensure the efficient production of potable water in the context of different climate change scenarios. The scope of Vitens is limited (for this analysis) tot the continuity of its service towards its household and industry clients and the protection of its reputation toward the relevant stakeholders. This last point is specified as keeping the image of being a sustainable and environmental friendly company

Table 5.3: VITENS RS – Objectives and sources of the risk assessment process of the Provincial Government

RISK OWNER	OBJECTIVES	SCOPES	SPECIFIC OBJECTIVES	Risk Assessment extent			Risk Treatment	
				Identification	Analysis	Evaluation	SITE SPECIFIC	GOVERNANCE
Public Water Supply utility **VITENS**	**Assure efficient production of drinking water** ***in climate change scenarios***	**Service continuity**: Water provision for public water supply and for other consumers (industry)	Assure sufficient **volumes** of water supply during 365 days/year for drinking water and all industrial costumers	✓	✓	✓	**YES**	Water resources governance
		Protect **reputation** of Vitens	Keep and improve positive **image** of sustainable and environmental friendly company					

5.3.2 Hazards, risk sources and risk factors

Table 5.4 shows the hazard, risk sources and risk factors for Vitens. The hazard of operational drought is a direct consequence of decisions made by the province, increased demand by its consumers and problems in the distribution net due to increased temperature. The drought hazard is affected by the same risk factors as for the province, since they both are grounded in the balance between demand and supply of water. The consequences of drought are negatively affected by peak water demands in the summer. For managing it reputation, Vitens reports fake news as one of the big risk factors. The automatic spreading of fake news through IT systems greatly aggravates the consequences thereof.

Table 5.4: Hazard, risk sources and risk factors affecting VITENS objectives

Risk Category			HAZARD	HAZARD		CONSEQUENCES	
NRISK OWER	SCOPES	SPECIFIC OBJECTIVES		HAZARD source(s)	Risk FACTORS Affecting Hazard likelihood	ELEMENTS at risk (Exposure)	Risk FACTORS Affecting Consequences
Public Water Supply utility VITENS	**Service continuity**: Water provision for public water supply and for other consumers (industry)	Assure sufficient **volumes** of water supply during 365 days/year for drinking water and all industrial costumers	Operational drought = licensed abstraction volumes and /or quality are insufficient to meet public water demand	Provincial government reduces abstraction rights due to operational drought in regional water system (see above) Increased drinking water demand due to warming and heat stress (see above) Heat stress which increases the growth of algae and bacteria in distribution pipelines, possibly locally affecting the quality of public water supply	– Reduced groundwater quantity due to changing evatransporation and rainfall patterns – Soil degradation due to unsustainable land-use, affecting the quality of the soil and groundwater system. – Increased pressure on land-use for urbanization and tourism, increasing the risk of contaminations in groundwater resources. – Urbanization (tourism infrastructure), leading to more heat stress.	Public water supply service	– Peak demands in summer
	Protect **reputation** of Vitens	Keep and improve positive **image** of sustainable and environmental friendly company	Damages to the reputation of Vitens, leading to a decreased consumer trust	(Social) media messages reporting on horror stories drinking water, or alleged wrongdoings of Vitens	Spread of fake news (post-fact society)	Reputation of Vitens	Improved IT technologies which allow (fake) messages to spread fastly through internet

5.4. Summary and remarks

Both the province and Vitens have most to fear from long term drought. The effects of droughts are aggravated by the accompanying temperature increases and the increased demand in potable water. The Province is ultimately responsible for water resource management and its decisions have a direct effect on a broad range of stakeholders in the area. Vitens is one of the primary stakeholders, when it comes to groundwater management, and the decisions of the Province are a direct hazard to its operation. Apart from that, Vitens, being the main abstractor of Veluwe groundwater, has to maintain its reputation towards the other Veluwe stakeholders of being sustainable and environmental friendly.

6 RISK IDENTIFICATION AT TROODOS RESEARCH SITE

6.1. Brief research site introduction

The Peristerona Watershed (112 km^2) is located along the northern slopes of the Troodos Mountains in Cyprus. The Peristerona River flows from the northern flank of the Troodos Mountains into the Mesaoria Plain (Figure 6.1). The climate along the northern slopes of Troodos is classified as semi-arid, while the mountains at higher elevations are classified as dry sub-humid (Bruggeman et al., 2015). The long-term average annual precipitation (1980-2010) was 754 mm at Polystypos (1100 m above sea level/asl) in the mountains of the Peristerona Watershed. In the foothills, precipitation was 405 mm at Panagia Bridge (440 m asl), and 270 mm at Peristerona (200 m asl) in the plain. The lowest annual rainfall in Peristerona in the 30 year record, observed during the 2007-08 hydrologic year, was 126 mm, followed by 138 mm (1990-91). Daily rainfall maxima during the 30 year period were 139 mm in Polystipos (2 December 2001), 157 mm in Panagia Bridge and 100 mm in Peristerona, both on 18 January 2010. The long-term (1980-2010) average monthly daily minimum temperatures in January (coldest month) were 3 ºC in the mountains in Agros (1015 m asl) and 16 ºC in Astromeritis (200 m asl) in the plain. The average daily maximum temperatures in July and August were 31 ºC in Agros and 35 0C in Astromeritis. In the upstream and midstream areas of the Peristerona Watershed the geology is dominated by the diabase and basal group formations, intrusive rocks of the Troodos ophiolitic sequence that form a heterogeneous fractured aquifer system (Mederer, 2009). In the Mesaoria plain, the geology of the river narrow valley mainly consists of river alluvium, which overlays the Pleistocene member of the Circum Troodos sedimentary basin.

Figure 6.1: Google Earth image (4 April 2015) of the Peristerona Watershed (green), Panagia Bridge Station (light blue) community boundaries (pink), the UN buffer zone (red) and the research focus area (yellow). The map is oriented with North to the right

The Peristerona River is an ephemeral stream, which does not flow in summer. Surface runoff is highly variable. The average long-term annual stream flow at Panagia Bridge station in the foothills of Peristerona Watershed is 11.75 Mm3 (1980-2010). Lowest annual flow was 1.85 Mm3 (2008) and the maximum was 25.94 Mm3 (2002). The streamflows from the Troodos recharge the groundwater formations in the Mesaoria Plain. Gabion check dams have been established across the riverbed to slow the stream flow and increase groundwater recharge in the downstream areas of the watershed. The downstream area of the Peristerona Watershed has been declared a nitrate vulnerable area (MANRE, 2012). High nitrate concentrations have been observed in boreholes in the downstream area. Levels in excess of 50 ppm have been found in one of the boreholes. Intensive pig farms in the river valley most likely contribute to the high nitrate levels. In addition, up to recently the area did not have a domestic sewage network.

According to the Census of Agriculture (Cystat, 2014), agricultural cropland, including fallow, in the Peristerona Watershed's communities covered 3273 ha in 2010. In 2013, lands in good agricultural conditions, which were submitted and qualified for Single Area Payment support, totalled 3546 ha (Cyprus Agricultural Payment Organization datasets). In the foothills and downstream areas, we find both rainfed and irrigated crops. Cereals, especially barley, are the main rainfed crop. Barley is generally grown for animal feed and often harvested and bailed whole, especially in dry years. Irrigated crops are found on small fields and terraces along the river (olives, vegetables), especially in Agia Marina and in the plain downstream from Peristerona community. Throughout the watershed there are diversions from the stream, which supply irrigation water to the fields by gravity through a system of open channels. Groundwater pumping is also common, especially in the alluvial river aquifer. Streamflow does not reach the downstream communities during dry years.

Downstream, the research system is defined by the boundaries of the communities of Kato Moni, Orounda, Peristerona and Astromeritis. The community of Astromeritis lies outside the watershed boundaries but receives irrigation water, diverted through open canals, from the Peristerona River. The downstream area of the Peristerona Watershed is very narrow, but the land of the communities also covers the neighbouring plains.

6.2. Public water supply

6.2.1 *Scopes and objectives of the RMP*

The objective of the RMP for the domestic water supply is to develop strategies for climate change adaptation that manage the risk of water supply continuity failure due to the insufficient water availability caused by abstraction of groundwater resources and the water quality degradation caused by pollution and climate change impacts (Table 6.1).

Table 6.1: TROODOS RS – Objectives and scopes of the risk assessment processes of the Community Councils of Downstream Peristerona Watershed

RISK OWNER	OBJECTIVES	SCOPES	SPECIFIC OBJECTIVES	Risk Assesment extent			Risk Treatment	
				Identification	Analysis	Evaluation	Site specific	GOVERNANCE
COMMUNITY COUNCILS of Downstream Peristerona Watershed	Supply drinking water to community households	Continuity of water supply	To supply water in adequate quantity and at affordable cost	✓	✓	✓	YES	Water resource governance
			To supply water with adequate quality (i.e., that it will not harm customers' health)					

The risk owners for the domestic water supply sector of Peristerona Watershed are the Community Councils of downstream areas. The downstream communities rely exclusively on groundwater for domestic water supply. The main risk scopes of the Community Councils are: (a) to ensure the continuity of water supply to rural households for domestic use, and (b) to ensure the good quality of drinking water.

6.2.2 Hazards, risk sources and risk factors

Three main hazards for the domestic water supply sector are identified, namely, low river flows, low groundwater recharge and insufficient water resources for rural households' domestic supply (Table 6.2). These hazards are mainly triggered (i.e., hazard sources) from the reduction and increased variability of precipitation and the increase in water demand for domestic use. The main risk factors that affect the hazard likelihood are economic development, population change, which increase the domestic water demand as well as factors such as the low adoption of modern technologies by Community Councils (e.g., leak detection systems), which could improve water management and reduce water losses. A fourth hazard for the sector is poor water quality (under supplying water with adequate quality risk objective), which is mainly triggered by the reduction and increased variability of precipitation, the overuse of agricultural fertilizers and pesticides, the non-sustainable management of livestock waste (e.g., manure) and the existence of old water supply infrastructure. The main risk factors that affect the poor water quality hazard are: the low enforcement of agri-environmental regulations; the expansion of livestock holdings; the insufficient agricultural extension and advisory services; the limited investments for the maintenance and/or replacement of water supply infrastructure; and the low technical preparedness of Community Councils to cope with and adapt to climate change impacts.

The main elements (receptors and/or assets) that can be harmed if exposed to the aforementioned hazards are: the health of rural inhabitants due to water scarcity and quality; the value of the residential and commercial property; the depreciation of public infrastructure as well as the deterioration of environmental resources. The design and implementation of alternative options for securing the continuity of domestic water supply (e.g., desalination) in conjunction with proper water testing and treatment systems can mitigate elements' exposure to hazards. On the contrary, the lack of technical expertise and knowledge, since domestic water supply management practices are mainly based on empirical knowledge, can further deteriorate elements' exposure to hazards.

Table 6.2: Hazard, risk factors and consequences of the risk management processes of the Community Councils

RISK OWNER	Risk Category: SCOPES	Risk Category: SPECIFIC OBJECTIVES	HAZARD	HAZARD: Hazard sources	HAZARD: Risk Factors (Affecting Hazard likelihood)	CONSEQUENCES: Elements (Exposure)	CONSEQUENCES: Risk FACTORS (Affecting Consequences)
COMMUNITY COUNCILS of Downstream Peristerona Watershed	Continuity of water supply	Supply water in adequate quantity and at affordable cost	- Low river flows - Low groundwater recharge (hydrological drought) - Insufficient water resources for domestic supply (operational drought)	- Reduction and increased variability of precipitation - Increase in domestic water demand	- Economic development - Population change - Low adoption of technologies (e.g., leak-detection systems)	- Rural inhabitants - Residential property - Commercial property - Infrastructure - Environment	- Lack of technical expertise and knowledge - Alternative options for securing the continuity of domestic water supply (e.g., desalination)
		Supply water with adequate quality	- Poor water quality	- Reduction and increased variability of precipitation - Agricultural chemicals (fertilizer, pesticides) - Livestock waste (manure) - Old water supply infrastructure	- Enforcement of agri-environmental regulations - Expansion of livestock farms - Agricultural extension and advisory services - Investments/funding for the maintenance/replacement of water supply infrastructure - Technical preparedness to cope and adapt	- Human health - Residential property - Commercial property - Environment	- Water testing and treatment systems - Alternative options for securing the continuity of domestic water supply (e.g., desalination)

6.2.3 Events

Based on the hazard sources identified in the Section 6.2.2, three main hazard pathways have been identified for the domestic water supply sector, namely, groundwater resources reduction, water resources deficit and deterioration of water quality (Table 6.3). These hazard pathways have detrimental effects on human health, value of property (residential and commercial), public infrastructure and the overall status of environment. The main causes that may result in the risk events occurring are: low precipitation during an extended period; low groundwater recharge; increase in water demand; and poor maintenance of water supply systems. Primary consequences of these events may include disruption of water supply, overexploitation of water resources, environmental degradation and negative effects on human health due to water contamination. Secondary and tertiary effects may include severe economic losses for several production sectors and rural depopulation.

Table 6.3: Description of events, hazards sources and consequences on RMP objectives for domestic water supply

EVENTS			
Event description		**Causes** (set of Hazard Sources)	**Consequences** (on RMP objectives)
Hazard pathways	**Elements impacted**		
- Groundwater resources reduction - Water resources deficit - Deterioration of water quality	- Human health - Residential property - Commercial property - Infrastructure - Environment	- Low precipitation during an extended period - Low groundwater recharge - Increase in water demand - Poor maintenance/ modernization of water supply infrastructures	- Disruption of water service - Overexploitation of water resources - Environmental degradation - Human health effect - Economic losses for several sectors - Rural depopulation

6.3. Agriculture

6.3.1 Scopes and objectives of the RMP

The objective of the RMP for agriculture is to develop strategies for the adaptation of the sector to climate change, i.e., low precipitation and drought conditions, which aim: (a) to match water demand with available water supply (mainly groundwater), and (b) to reduce water losses, thus ensuring a fair, efficient and sustainable management of irrigation water supply.

The risk owners for the agricultural sector of Peristerona Watershed are the irrigation associations and divisions of the downstream communities (Kato Moni, Orounda, Peristerona and Astromeritis). The main risk scopes of irrigation associations are: (a) to ensure sufficient amount of water for irrigated agriculture (mainly originated from boreholes or river diversions), and (b) to maintain irrigation water supply system in good condition (e.g., pumps, pipes, concrete channels).

6.3.2 Hazards, risk sources and risk factors

The main hazards for the agricultural sector of Peristerona Watershed are: the low and variable precipitation; the low river flows; the low groundwater recharge; and the water scarcity for food production (Table 6.4). These hazards are mainly driven from the reduction and increased variability of precipitation, the increase in temperature and the increase in irrigation water demand. The main risk factors that affect the likelihood of those hazards are: climate change; the weather and hydrologic forecast capability; the unsustainable use of groundwater resources; and the low level of adoption of irrigation technologies. Another major hazard related with the irrigation supply systems conditions relates to water scarcity for food production. This hazard is mainly triggered by the frequency and intensity of extreme precipitation events as well as the presence of old irrigation water supply systems. The poor maintenance of the infrastructure, the limited funding for replacing old water supply systems, the limited agricultural insurance markets and the low technical preparedness of farmers to cope with and adapt to climate change challenges further increase hazards' likelihood.

The main elements harmed if exposed to the aforementioned hazards are the viability of the agricultural sector and the sustainability of water and environmental resources. Farm education, including issues such as water conservation innovation and climate change adaptation and mitigation, as well as awareness of farmers on support opportunities can foster the adoption of irrigation water technologies and further mitigate hazards' consequences. Similarly, the level of investment for the replacement of old water supply infrastructure as well as its maintenance can also affect hazards' consequences. Finally, the volatility of the agricultural product prices and energy prices directly affect the viability of agricultural sector.

Table 6.4: Hazards, risk factors and consequences of the risk management processes of the irrigation associations

	Risk Category			Hazard		Consequences	
RISK OWNER	SCOPES	SPECIFIC OBJECTIVES	Hazard	Hazard sources	Risk Factors Affecting Hazard likelihood	Elements (Exposure)	Risk FACTORS Affecting Consequences
Irrigation association of Peristerona	Ensure fair, efficient and sustainable management of irrigation water supply	Match demand with sustainable supply	- Low and variable precipitation (agricultural drought) - Low river flows - Low groundwater recharge (hydrological drought) - Water scarcity for food production (operational drought)	- Reduction and increased variability of precipitation - Increase in temperature Increase in irrigation water demand	- Climate change Weather and hydrologic forecast capability (seasonal) - Unsustainable use of groundwater resources - Low level of adoption of irrigation technologies	- Agriculture - Water resources - Environment	- Farm education - Adoption of irrigation technologies - Volatility of agricultural product prices - Volatility of energy prices
	Efficient management, conservation and exploitation of the Public Irrigation Infrastructures of the Sorraia Valley	Reduce water losses	- Water scarcity for food production	- Extreme precipitation events - Old water supply infrastructure	-Maintenance of water supply infrastructure - Funding for replacing old water supply infrastructure - Technical preparedness to cope and adapt - Uninsured sector	- Agriculture - Water - resources	- Level of investment for the replacement of old water supply infrastructure - Awareness of farmers & farmers associations on support opportunities - Maintenance of water supply systems and networks

6.3.3 *Events*

Based on the hazard sources identified in the Section 6.3.2, four main hazard pathways have been identified for the agricultural sector, namely, stream flow reduction, groundwater resources reduction, low water availability for irrigation and deterioration of irrigation infrastructure (Table 6.5). These hazard pathways negatively affect the viability of agricultural sector, foster rural depopulation and enhance environmental and landscape degradation. The main causes that may result in the risk events occurring are: low precipitation and high temperatures; low groundwater recharge; increase in irrigation water demand; and low adoption of modern irrigation technologies. Primary consequences of the events may include the disruption of irrigation water supply, the overexploitation of water resources and the overall environmental degradation. Secondary and tertiary effects may include depreciation of irrigation water supply infrastructure, loss of agricultural land, loss of agricultural jobs, which will create wider negative economic impacts in rural areas.

Table 6.5: Troodos RMP – Description of events, hazards sources and consequences on RMP objectives for agriculture.

Events			
Event description		Causes	Consequences
Hazard pathways	Elements impacted	(set of Hazard Sources)	(on RMP objectives)
- Stream flow reduction - Groundwater resources reduction - Low water availability for irrigation - Deterioration of irrigation infrastructure	- Agriculture - Rural areas (depopulation) - Environment - Landscape	- Low precipitation during an extended period - High temperatures - Low groundwater recharge - Increase in irrigation water demand - Low adoption of modern irrigation scheduling technologies	- Disruption of irrigation water supply - Overexploitation of water resources - Environmental degradation - Depreciation of infrastructure - Loss of jobs - Loss of agricultural land - Wider economic impacts in rural areas

6.4. Summary and remarks

The RMP in Cyprus is conducted in the downstream communities of the Peristerona Watershed. The main objective of the research is to develop strategies for climate change adaptation for the two main water uses, namely, the domestic water supply and the agriculture. The hazards in both sectors are triggered by both climatic (e.g., reduction of precipitation and increase in temperatures) and anthropogenic (e.g., sustainable management of livestock waste) factors. In the case of the domestic water supply, the most important element exposed to the identified hazards is the health of rural inhabitants; the presence of alternative options for securing the continuity of domestic water supply e.g., desalinated water, is the most important factor for mitigating human health exposure to hazards. In the case of agriculture, the most important elements exposed to the identified hazards are the viability of the sector and the quantitative and qualitative status of water resources; soft and managerial adaptation options such as farm training and awareness of farmers on support opportunities can help farmers better adapt to a changing environment and mitigate sector's exposure to hazards.

7 RISK IDENTIFICATION AT TAGUS RESEARCH SITE

7.1. Brief research site introduction

The Portuguese research site, located in the lower Tagus river basin, addresses climate change adaptation of two key sectors, one concerning an important public service, public water supply, and the other concerning agriculture, one of the most relevant economic activities in the region.

Reduction in water availability and quality degradation, associated with more frequent and intense droughts, are the main concerns of both sectors but, in some specific cases, inundations are also of concern, essentially if they are due to storm surges in the estuary promoting farming lands inundation with saline water.

The **public water supply sector** is represented in BINGO by EPAL, the oldest water company of Portugal that supplies Lisbon city and other surroundings 35 municipalities of the right margin of the river Tagus. EPAL doesn't hold private water sources. On the contrary, it has to share water resources with other users. Climate change adaptation objective of EPAL in BINGO is to develop strategies to assure water supply continuity, in case of reduction of water resources availability or quality degradation caused by climate changes. Water resources governance is a key issue for EPAL.

The **agriculture sector** in Tagus RS is focused in two different realities. The first concerns two different cases of public irrigation perimeters (PIP) in the left lower margin of Tagus river: the **Sorraia Valley** and the **Lezíria Grande de Vila Franca de Xira** – LGVFX (hereinafter called "Lezíria Grande") (Figure 7.1). A public irrigation perimeter means that the irrigation infrastructures (storage, transportation and primary distribution networks) were built or funded by the Portuguese Government, but farming lands and agriculture practices are private. A third case relates to the farmers of the remaining important agricultural area of the lower Tagus (**Lezíria do Vale do Tejo – LVT**). As the majority does not benefit from public irrigation infrastructures, they represent a distinct reality. The exception is farmers benefiting from Vala do Tejo, a public irrigation channel fed directly by Tagus flow. In practice it functions like a tributary of the Tagus River. Groundwater sources are quite common in the region. Water resources governance related risks concerning those farmers will be identified, in order to contribute to overall governance suggestions of improvement, to be developed in BINGO work package 5.

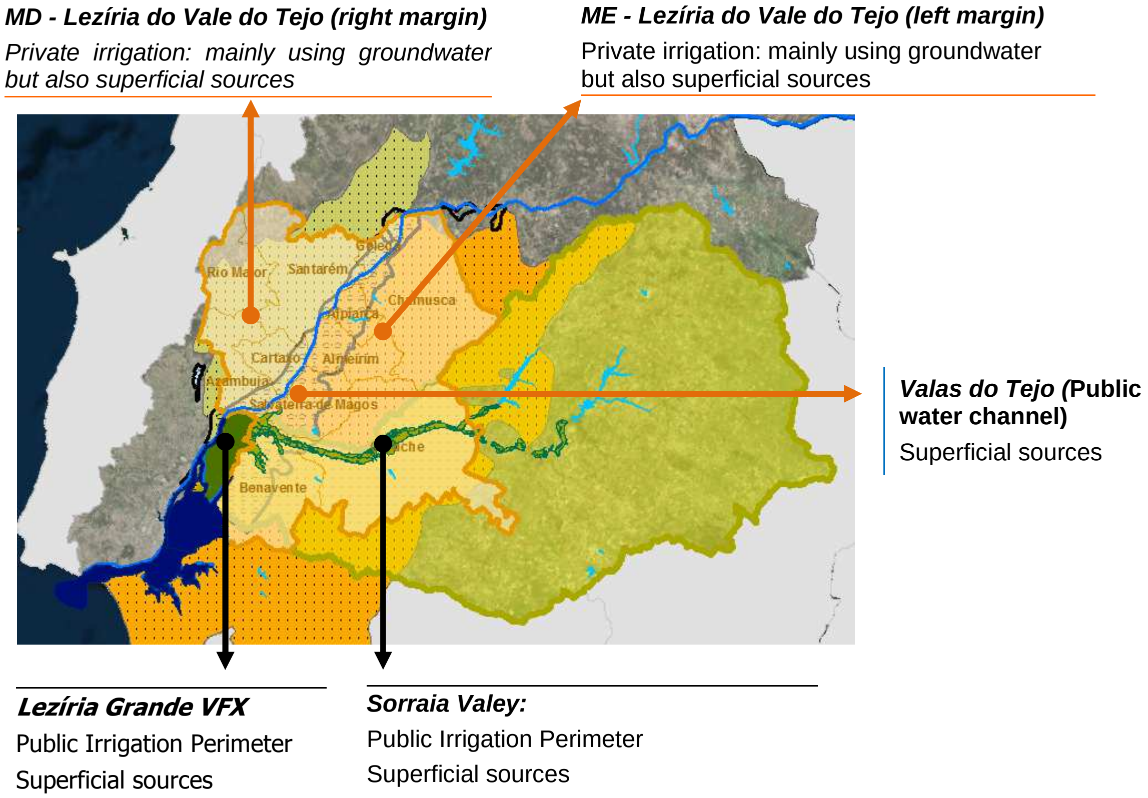


Figure 7.1: Most representative types of irrigation sources in the Tagus RS

The main agriculture objective of the **agriculture sector** in BINGO is to strengthen this economic sector by developing strategies for climate change adaptation in the region under low precipitation (droughts) and to identify the risk associated with estuarine inundation due to spring tides combined with storms surges and sea level rise scenarios. How governance can be improved to facilitate sectoral adaptation is a key issue to be addressed. Adaptation in BINGO project is focused on the agricultural agro-ecological system rather than on the socio-economic system (Figure 7.2).

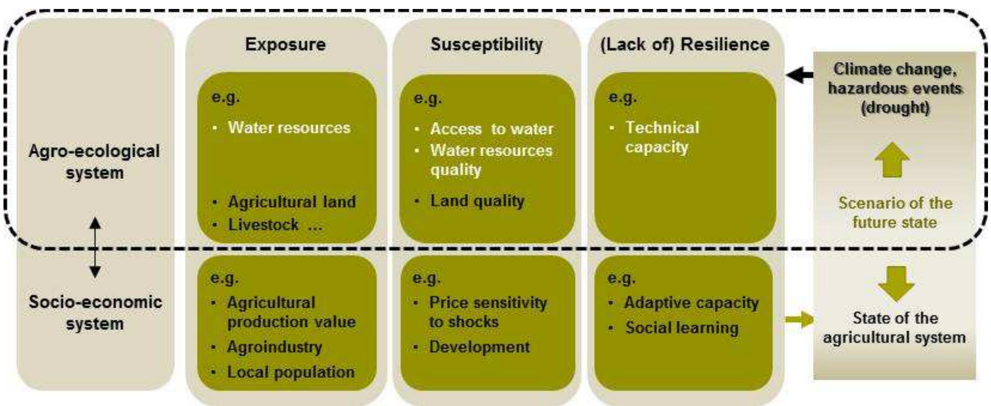


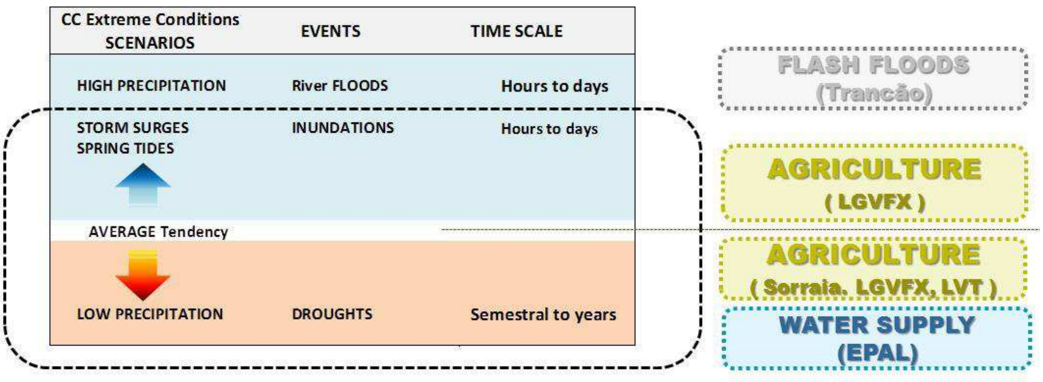
Figure 7.2: Agricultural system. Adapted from Aleksandrova *et al.* (2016)

Other important water uses exist in the region, for example hydroelectric production and other public water supply entities both on the left and right Tagus margin. They all compete for the same limited water resources.

In summary, water resources governance is a key transversal issue of the Tagus research site climate change adaptation under low precipitation.

People safety and property protection against flash flooding is being addressed in Trancão river basin, an affluent of the Tagus River. The existing hazard to people and property was estimated.

Figure 7.3 summarises the case studies being addressed in the Portuguese research site. The following subchapters will address the risk approach to be used to support later adaptation strategies definition.



Legend:	EPAL	Public Water Supply utility
	LGVFX	Lezíria Grande de Vila Franca de Xira
	LVT	Lezíria do Vale do Tejo (or Lezíria do Tejo)

Figure 7.3: Case studies addressed in Tagus research site

7.2. Public Water Supply – EPAL

7.2.1 Scopes and objectives of the RMP

The BINGO climate change adaptation objective of EPAL Public water supply utility is to manage the risk of reduction of water production, due to insufficient water availability or quality, due to depletion of water resources (superficial or groundwater) or quality degradation caused by climate change impacts in water resources. From EPAL's perspective, risks related to climate change are seen as truly strategic, given the fact that a range of consequences may arise from several risk categories, beside quality and quantity of water supplied, such as service reliability, business sustainability, profitability and reputation.

The main concerns are *(i)* to conclude if climate change is an added risk to climate variability for EPAL' water supply sources, both in quantitative and qualitative terms, leading to restrictions on the public service and *(ii)* to identify up to what extent the competition for the same resources by other entities, including the agriculture sector or the public supply to municipalities of the left bank of the Tagus River, will become a problem for local and strategic reserves of EPAL, an important preparedness measure in place; *iii)* if climate change impacts represents a source of risk for profitability and good image (reputation) will affect (Table 7.1).

Table 7.1: Tagus RS – Objectives and scopes of the risk assessment process of EPAL (PWS)

RISK OWNER	OBJECTIVES	SCOPES	SPECIFIC OBJECTIVES	Risk Assessment extent			Risk Treatment	
				Identification	Analysis	Evaluation	Site specific	GOVERNANCE
EPAL	**Assure efficient production of drinking water** in climate change scenarios	**Continuity of water production** (related to water intakes). *(Fulfil needs and expectations of customers)*	To supply water with adequate **quality** *(i.e., that it will not harm customers' health)*	✓	✓	✓	YES	Water resource government
			To supply water in adequate **quantity** *(i.e., meeting every customer's needs)*					
			To supply water with adequate **reliability** *(i.e., ensuring the continuity of the supply).*					
		Profitability	To achieve the economic and financial strategic objectives					
		Image	To ensure the **trust** from the customers as well as the **reputation** among other national or international water utilities					

Assure efficient production of drinking water is the objective of the full risk management process being performed within the BINGO project by EPAL, the risk owner. Attending to the above referred concerns, the risk management process was established with the scopes and objectives of Deliverable 4.1 summarised in Table 7.1 (Rocha *et al.,* 2017).

7.2.2 Hazards, risk sources and risk factors

Water resources shortage is the hazard under analysis. Chapter 6.2 of Deliverable 4.1 provides a characterization of EPAL Public water supply. Water resources (water intakes), water treatment plants and the transportation system are the main components of EPAL's drinking water production system. It also provides reference to the type of customers, representing the demand component of the water supply system. Competition for water resources is a risk that EPAL may be facing under adverse meteorological conditions, although in recent years episodes of water quality degradation forced this abstraction to stop for hours.

Hazard profile

So far, Valada superficial intake, located in Tagus River, is the single water source affected by meteorological conditions and operational upstream discharges. Flow variability, due to upstream hydropower production regime, salt water intrusion and contaminants concentration are the main hazard characteristics. Being a secondary water source (between 10 and 20% of total water supplied), impacts in this water source did not require supply interruption or reduction till the present.

Hazard, risk sources and risk factors

The risk sources and factors related to EPAL objectives are identified in Table 7.2.

7.2.3 Events

A set of plausible events and expected consequences is presented in Table 7.3. These events intend to distinguish impacts, therefore events that do not affecting EPAL performance events having economic losses for EPAL as the major consequence; and events resulting in insufficiency of supply to fulfil demand, affecting the community, were presented.

Table 7.2: Hazard, risk sources and risk factors affecting EPAL objectives

RISK OWNER	Risk Category: SCOPES	Risk Category: SPECIFIC OBJECTIVES	HAZARD	Risk SOURCES: HAZARD source(s)	Risk SOURCES: ELEMENTS at risk (Exposure/ hazard characteristics)		Risk FACTORS (Affecting Hazard likelihood or Consequences/Impacts (on elements at risk)): Related to:		Natural: Environmental	Man-induced: Physical		Man-induced: Human (Water Resources Management)	
EPAL	**Continuity of water production** (related to water intakes)	To supply water in adequate **quantity**	Failure of supplying water demanded due to: **Water resources shortage** (Unavailability or insufficiency of water at sources to fulfill demand)	**Abnormal low precipitation / Hydrological drought**	**WATER PRODUCTION SYSTEM (Quantity)**	**Water sources** (Hydrologic characteristics)	**Water resources availabity**	**C. Bode RESERVOIR** (level of storage)	Low Precipitation; Temperature increase (> Evaporation)	Storage: - Reservoir storage capacity; - Dam and components conditions; - Water discharges for Hydropower production.	(+)	**WRM practices:** - Spanish - Portuguese reservoirs convention / Bilateral regime of basins water resources sharing . E.g.: . agreed volumes and discharges regimes to PT; . decrease of volumes discharged to PT during exceptional meteorological conditions - EDP hydropower production regime based on internal factors (market, peaks, alternative production sources) not favouring other Tagus river users; - Lack of national clear water uses policy; - Lack of supervision of illegal uses - Drought management "rule" of 2 years water volume allocation for public water supply.	(-) (-) (-) (-) (+)
								TAGUS RIVER at Valada (river flow)	Modified River flow	Tagus Flows: - Spain regime of flows released to Portugal; - Hydropower production induced Tagus flows (due to upstream reservoirs' exploitation regimes and Spanish inflows); - Legal consumptive uses upstream Valada (mainly agriculture) - Illegal consumptive uses upstream Valada	(-) (-) (-)		
								GROUNDWATER strategic reserves (quantitative status)	Precipitation (low quantity and temporal distribution)	- Land use - Surrounding consumptive uses (Agriculture or PWS) - Agriculture induced recharge (e.g. agricultural irrigation practices)			
							Demand		Temperature increase	- EPAL' transportation network condition - EPAL's clients infrastructures condition		- EPAL's clients behaviour i) Bulk Water clients (Municipalities; some Industries) and ii) Distribution clients (Domestic; Commerce & Industry; State; Fire departments; Lisbon municipality).	
						EPAL production operationality	**EPAL**			*Access to water:* - EPAL water intake Infrastructures conditions (e.g. spur and oscillating masts conditions at Valada) *Transport:* - EPAL' transportation netwok design (e.g. redundancy)		EPAL Preparadness and Resilience: - EPAL's risk culture; - EPAL's production flexibility to adapt; - Contingency plans (e.g. apportionment strategy in place).	(+) (+) (+)
		To supply water in adequate **quality**	**Deficient quality of water at sources** (Presence of contaminants at water sources)	**Occurence of wild fires**	**WATER PRODUCTION SYSTEM (Quality)**	**Water sources** (Presence of contaminants)	**Water sources quality**	**C. Bode RESERVOIR** (Ashes and other contaminants)	Contaminants deposition and soil leaching from forest fires	Land use and leaching of contaminants		*WRM practices:* - Existence of a Reservoir protection perimeter	(+)
				Temperature increase **Sea level rise**				**TAGUS RIVER at Valada** (Oxygen Concent.; Salinity increase; Microbiological concent. increase; Chemical contaminants increase)	Temperature; Salt water intrusion	Discharge of contaminants in the river: - Spanish pollutant discharges to Portugal; - Legal Pollutant discharges in national Tagus basin (e.g. domestic sewerage from Nabão sub basin); - Illegal Pollutant discharges	(-)	*WRM practices:* - Noncompliance of good status of Spanish water bodies close to the border; - National water bodies objectives and delay in good status achievement (e.g. Nabão); - Licensing policy; - Lack of supervision of national illegal discharges.	(-)
								GROUNDWATER strategic reserves (Salinity, contaminants)	- Salt water intrusion; - River - groundwater interactions; - Soil - groundwater interactions	Discharge of contaminants: - Agricultural irrigation techniques - Intensive livestock	(-) (-)	*WRM practices:* - Existance of well protection perimeter for PWS; - CAP environmental protection policy (conditionality); - Agricultural practices (irrigation, fertilization and phytosanitary products application).	(+) (-)
				Presence of contaminants		**Water Treatment Plants**	**EPAL Water Treatment capacity**		Contaminants concentration at water sources	Characteristics of WTPs and Chlorination points: - Asseiceira WTP condition /efficacy (C. Bode source) - Vale da Pedra WTP condition /efficacy (Valada source) - Chlorination of groundwater source		*EPAL Preparedness and Resilience:* - EPAL's risk culture; - EPAL's water treatment flexibility to adapt; - Contingency plans	(+)
		To supply water with adequate **reliability**	**Interruption of water supply** (due to lack of integrity of infrastrucutres)	**Wild fires** *(and abnormal flooding)*	**WATER PRODUCTION Infrastructures: Intake, WTP or transport**		**Infrastructures**		Land use; Land slope.	- Physica protection - Redundancy - Existence of SCADA		EPAL Preparedness (Contingency plans)	(+)

RISK OWNER	Risk Category: SCOPES	Risk Category: SPECIFIC OBJECTIVES	HAZARD	Risk SOURCES: HAZARD source(s)	Risk SOURCES: ELEMENTS at risk (Exposure/ hazard characteristics)	Risk FACTORS (Affecting Hazard likelihood or Consequences/Impacts (on elements at risk)): Related to:	Natural: Environmental	Man-induced: Physical		Man-induced: Human (Water Resources Management)	
EPAL	**Profitability:** Ensure adequate profitability	To achieve the **economic and financial** strategic objectives	**Increase in the cost of energy** (due to higher elevation heights and/or to the need to action additional treatment steps at WTP and/or to import water from other systems)	**Abnormal low precipitation / Hydrological drought**	**WATER production and supply system:** Intakes; pumping stations; WTP; overall water supply	**EPAL costs of operationality**		Efficiency of pumps and other eletric equipment		- Price of energy - Price of chemicals	
	Image	To ensure the **trust** from the **customers** as well as the **reputation** among other national or international **water utilities**	**Diminished levels of service**	**Droughts** *(and floods or wild fires)*	**Customers' perception of level of service**	**Communication**				EPAL Communication strategy in place *(e.g. Timely sensibilization and information campaigns)*	

Table 7.3: Events design for EPAL

Event	EVENTS								
	CAUSES (set of Hazard Sources)	EVENT description			CONSEQUENCES				
					on EPAL RMP objectives				On Clients
		Water sources	HAZARD pathways	Production of water	Supply water demanded with quality	Economic and financial	Reputation		
1	Abnormal low precipitation during **ONE** hydrologic year	C. Bode	Reduced inflow to Castelo. do Bode, existing sufficient storage to fulfil demand (EDP & EPAL)	83%	none	none	none		none
		Valada	Reduction of Spanish releases to PT → flow in Tagus river lower than average, **without significant impact on raw water quality**.	10%					
		GW reserves	Reduction of recharge	7%					
2	Abnormal low precipitation during TWO hydrological year	C. Bode	Reduced inflow to Castelo do Bode, existing sufficient storage to fulfil demand (EDP & EPAL)	83%	none	Financial losses due to increase of bulk pumping costs (> energy consumption)	none		none
		Valada	Reduction of Spanish releases to PT --> flow in Tagus river lower than average, **without significant impact on raw water quality**	10%					
		GW reserves	Reduction of recharge	7%					
3	Abnormal low precipitation during **THREE** hydrologic years	C. Bode	Reduced inflow to Castelo do Bode, insufficient storage to fulfil demand (EDP & EPAL) - **Reduction (10%) on CB contribution to the system** (compensated with Valada subsystem)	75%	none	Financial losses due to costs increase of: Bulk pumping costs (> energy consumption); Water treatment (chemicals)	none		none
		Valada	Reduction of Spanish releases to PT --> very low flow in Tagus river, **without significant impact on raw water quality**. Increasing in Valada contribution to the system, as VP WTP is able to cope with raw water degradation	18%					
		GW reserves	Low recharge during 3 consecutive years + increase in surrounding abstractions reduced quantitative status, but still sufficient to complement EPAL needs	7%					
4	Abnormal low precipitation during **THREE** hydrological year	C. Bode	Reduced inflow to Castelo do Bode, insufficient storage to fulfil demand (EDP & EPAL) - **Reduction (20%) on CB contribution to the system** (compensated with Valada subsystem)	66%	none	Financial losses due to costs increase of: - Bulk pumping costs (> energy consumption); - water treatment (chemicals)	none		none
		Valada	Reduction of Spanish releases to PT --> very low flow in Tagus river, **with mild impact on raw water quality**. Increasing in Valada contribution to the system, as VP WTP is able to cope with raw water degradation	27%					
		GW reserves	Low recharge during 3 consecutive years + increase in surrounding abstractions reduced quantitative status, but still sufficient to complement EPAL needs	7%					

	EVENTS							
Event	**CAUSES** (set of Hazard Sources)	**EVENT description**			**CONSEQUENCES**			
					on EPAL RMP objectives			**On Clients**
		Water sources	**HAZARD pathways**	**Production of water**	**Supply water demanded with quality**	**Economic and financial**	**Reputation**	
5	Abnormal low precipitation during **FOUR** hydrologic years	C. Bode	Reduced inflow to Castelo do Bode, insufficient storage to fulfil demand (EDP & EPAL) - Reduction (40%) on CB contribution to the system	a)50% b)54%	Fulfilment of 93% of initial demand	Financial losses due to: - Bulk pumping costs (> energy consumption); - water treatment (chemicals) - reduction on revenue due to less water supplied;	Some damage to ancient good reputation	A short number of clients are affected, as campaigns to reduce demand have a positive effect. Apportioning strategy in place. Social concern installed
		Valada	Reduction of Spanish releases to PT --> very low flow in Tagus river, **with mild impact on raw water quality**. **Increasing Valada contribution to the system to its quantitative limit**, as VP WTP is able to cope with raw water degradation	a)36% b)39%				
		GW reserves	Low recharge during 4 consecutive years + increase in surrounding abstractions reduced quantitative status.	a)7% b) 7%				
6	Abnormal low precipitation during **FOUR** hydrologic years	C. Bode	Reduced inflow to C. do Bode, insufficient storage to fulfil demand (EDP & EPAL) + **Total failure in the shared management of the reservoir and the priority for public supply rule**. Reduction (50%) on CB contribution to the system (not fully compensated with Valada subsystem)	a)42% b)63%	Fulfilment of 67% of initial demand	Heavy Financial losses due to: - costs increase of Bulk pumping costs (> energy consumption); - reduction on revenue due to less water supplied; - losses of contracts, legal consequences, - Prosecutions and damage compensations to third parties.	Significant damage of reputation, with bad critics in media.	Great amount of clients affected. Apportioning strategy in place. Significant socio-economic impact
		Valada	Reduction of Spanish releases to PT --> very low flow in Tagus river, **with high impact on raw water quality.** Valada not compensating CB reduction**, increasing only 20% its current contribution**, as VP WTP is unable to cope with raw water degradation part of the time.	a)12% b)18%				
		GW reserves	Low recharge during 4 consecutive years + increase in surrounding abstractions reduced quantitative status. In the case of Lezírias, it still delivers a production near to its limit, increasing the overall GW contribution to 20%.	a)13% b)19%				
7	Abnormal low precipitation during **FOUR** hydrologic years	C. Bode	Reduced inflow to Castelo do Bode, insufficient storage to fulfil demand (EDP & EPAL) + **Total failure in the shared management of the reservoir and the priority for public supply rule.** Reduction (50%) on CB contribution to the system (not compensated with Valada subsystem)	a)42% b)74%	Fulfilment of 57% of initial demand	Heavy Financial losses due to: - costs increase of Bulk pumping costs (> energy consumption); - reduction on revenue due to less water supplied; - losses of contracts, legal consequences, - Prosecutions and damage compensations to third parties.	Catastrophic damage of reputation, with bad critics in media.	Great amount of clients affected. Apportioning strategy in place. Very significant socio-economic impact
		Valada	Reduction of Spanish releases to PT --> very low flow in Tagus river, w**ith high impact on raw water quality**. **Valada also reduces its current contribution in 20%,** as VP WTP is unable to cope with raw water degradation part of the time.	a)8% b)14%				
		GW reserves	Low recharge during 4 consecutive years + increase in surrounding abstractions reduced quantitative status, not sufficient to complement EPAL needs, as it is impossible to increase its current contribution.	a)7% b)12%				

a) percentage on initial demand; b) percentage on satisfied demand

7.3. Agriculture

7.3.1 Scopes and objectives of the RMP

The agricultural sector in the Tagus basin has two different realities. One addresses two cases of public irrigation perimeters (PIP), the **Sorraia Valley** - disposing of private storage capacity through damming - and the **Lezíria Grande de Vila Franca de Xira** ("Lezíria Grande") - totally dependent of the Tagus river flow. The second addresses the farmers **of Lezíria do Vale do Tejo – LVT** that do not benefit from public irrigation infrastructures. A characterization of the full agricultural system was provided in Deliverable 4.1, chapter 6.3.

The main objectives in BINGO are to strengthen the economic agriculture sector, by developing strategies for climate change adaptation in the lower Tagus under low precipitation (droughts) and to identify the risk associated with inundation due to spring tides combined with storms surges and sea level rise scenarios. How governance can be improved to facilitate sectoral adaptation is a key issue to be addressed. The way this broad goal is concretized in BINGO varies with the case study considered. The general objectives, scopes and specific objectives are presented in Table 7.4.

In the **two public irrigation perimeters** the risk assessment process has an objective directly related with the responsibilities and mission of the respective Irrigators Associations, the risk owners (management, conservation and exploitation of the public irrigation infrastructures). The scopes were focused according to BINGO context and objectives, and are the same in both cases. They intend to fulfil the farmer's expectations of being supplied with water demanded and the DGADR expectations, the national authority that supervises the public irrigation infrastructures.

In **Lezíria do Vale do Tejo (LVT)**, the risk identification scope is related with the water resources governance impacts in agriculture in LVT, more specifically, with the identification of the water resources governance practices that may compromise irrigation during agricultural campaigns under extreme weather conditions (droughts). Within BINGO this objective was formulated to contribute to comprehensive governance improvement suggestions for the Tagus, to be developed in WP5.

Table 7.4: Tagus RS - Objectives and scopes of the risk assessment processes of the Irrigators Associations and Farmers

RISK OWNER	OBJECTIVES	SCOPES	SPECIFIC OBJECTIVES	Risk Assessment extent			Risk Treatment	
				Identification	Analysis	Evaluation	SITE SPECIFIC	GOVERNANCE
ARBVS (Irrigators Association)	Assure efficient management, conservation and exploitation of the public irrigation infrastructures of the Sorraia Valley	Assure **supply of water demand** during agricultural campaigns under extreme weather conditions (droughts) *(Fulfil needs and expectations of associated and beneficiary farmers)*	Supply water **demanded**	✓	✓	✓	**YES**	Water resources & Agricultural sector (water related issues)
			Supply water in **due timing**					
		Preserve the **integrity and operability of infrastructures** *(Fulfil DGADR contractual expectations)*	Achieve low levels of **water losses**					
ABLGVFX (Irrigators Association)	Assure efficient management, conservation and exploitation of the public irrigation infrastructures of Lezíria Grande de Vila Franca de Xira	Assure **supply of water demand and quality** during agricultural campaigns under extreme weather conditions (droughts) *(Fulfil needs and expectations of associated and beneficiary farmers)*	Supply water **demanded**	✓	✓	✓	**no**	
			Supply water with **quality**					
		Preserve the **integrity and operability of infrastructures** *(Fulfil DGADR contractual expectations)*	Achieve low levels of **water losses**					
		Preserve the **integrity of agricultural lands** during extreme weather conditions (inundations)	Avoid **inundation** of agricultural lands					
FARMERS of Lezíria do Vale do Tejo	Strengthen the agriculture economic sector in Lezíria do Vale do Tejo	Analyse **water resources governance** impacts in agriculture in Lezíria do Vale do Tejo	Identify the **water resources governance practices** that may compromise irrigation during agricultural campaigns under extreme weather conditions (droughts)	✓			**no**	

7.3.2 *Hazards, risk sources and risk factors*

7.3.2.1. Sorraia Valley

Hazard profile

The main feature of the Sorraia Valley PIP is its storage capacity (≈ 325 hm^3), able to endure at least one year of drought. The rain induced flow is stored mainly in 2 dams

(Maranhão and Montargil), that under normal meteorological conditions, provide enough water storage for agricultural campaigns, hydropower production and for other minor uses as agroindustry. As a result of the storage, in the beginning of each seasonal agricultural campaign farmers know in advance the water available for irrigation and can plan accordingly.

The Irrigators Association (ARBVS) is the entity in charge of maintaining the public irrigation infrastructures (reservoirs, transportation and distribution network and mini-hydroelectric) and of managing the water resources according to licenses issued by the National Irrigation Authority (DGADR) and the Regional Water Authority (ARH Tejo). The water abstraction licence represents up to about 70% of the total storage capacity. This value was set according to the historical water supplied to farmers within the perimeter and other minor clients. The remaining 30% is an important volume of public water reserved for future needs.

The risk profile of Sorraia PIP has been changing along the last two decades.

Water resources availability - Water sources (rain fed reservoirs) have been maintained stable along time but an additional operational storage has been installed recently, increasing total water availability for usage. This “operational storage” collects the surplus water of the transportation network downstream, processed in open channels, and the river residual agricultural runoff. Presently, in years of reduced precipitation almost all the water precipitated in the basin remains in the basin, due to the improvement of basin water resources management. The flow released to the estuary is quite reduced in those years.

Demand - Efficiency of agricultural practices has been largely improved over the last two decades, therefore the water demanded by the original beneficiary farmers has strongly reduced over time. Having a surplus in average years, the Association acquired new clients; therefore, the total amount of water demand was not reduced over time, but reached more farmers. In average years, the water allocation is processed peacefully.

During droughts, an apportionment strategy is peacefully put in place, according to the clients profiles: irrigated annual or multi-annual cultures (olive grove, orchard, vineyard, walnut, eucalyptus); seasonal irrigated agriculture and agroindustry (Figure 7.4).

Rice, the most water demanding culture represents about 50% of the water use (Figure 7.5). Agroindustry is a minor consumer. Permanent cultures, first priority of water allocation, represent presently about 13 % of the total cultivated area.

Figure 7.5 illustrates the water supplied by ARBVS along the last three decades. Care must be taken when analysing water use tendencies based on this figure. Water supply variation is a result of the varying demand profile (efficiency increase); supply to new clients (more agricultural area benefiting from irrigation) and the precipitation and soil water requirements along the agricultural campaigns.

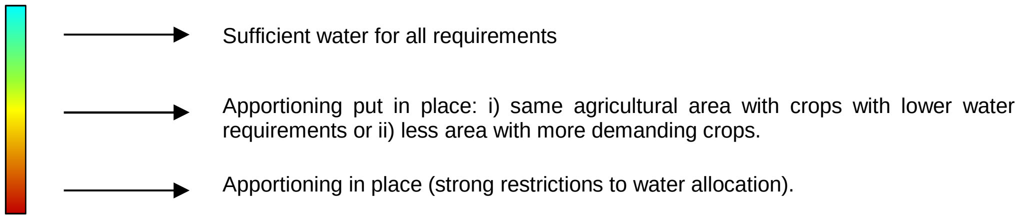


Figure 7.4: Apportioning strategy during droughts

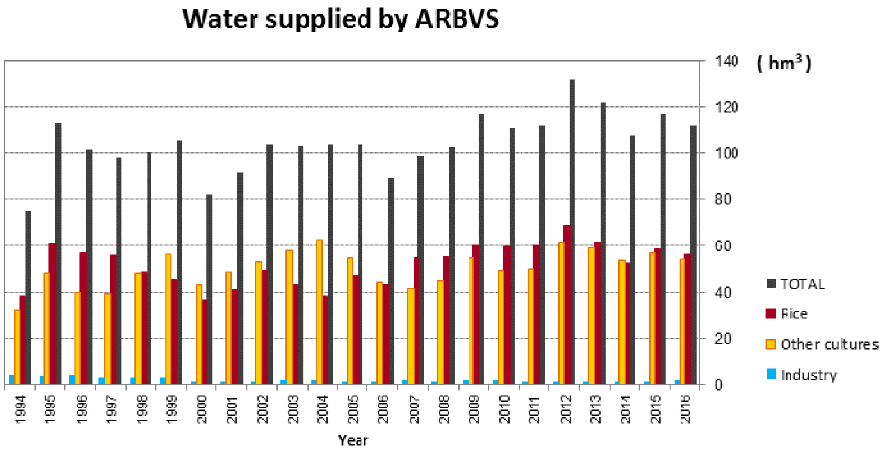


Figure 7.5: Water supplied by ARBVS along the last decades

So far, water apportioning was implemented only few times, the last ones in 1993 and in 2000. In 1993 the available water resources were only enough to irrigate permanent cultures and to supply agro industries. There was no water for any type of annual cultures and many farmers decided to grow sunflower (without water). The impact was significant in local seasonal agricultural employment and also in all services related to agriculture (seeds and fertilizers, machine work, etc.), because the land was not cultivated. It was a turning year. Water use efficiency was greatly improved since then. In 2000 there was a need for apportioning water, but without such a severe impact.

Hazard, risk sources and risk factors

BINGO project focus on the agricultural agro-ecological system (Figure 7.2). Water is the key resource under analysis and water resources shortage to fulfil demand (operational water resources drought) the main hazard considered. The risk sources and risk factors related to ARBVS objectives are identified in Table 7.5.

BINGO

Table 7.5: Hazard, risk sources and risk factors affecting ARBVS objectives

RISK OWNER	Risk Category: SCOPES	Risk Category: SPECIFIC OBJECTIVES	HAZARD	Risk SOURCES: HAZARD source(s)	Risk SOURCES: ELEMENTS at risk (Exposure/ hazard characteristics)	Risk FACTORS (Affecting Hazard likelihood or Consequences/Impacts (on elements at risk)): Related to:	Natural: Environmental	Man-induced: Physical		Man-induced: Human	
IRRIGATORS ASSOCIATIONS: ARBVS	**Assure supply of water demand** during agricultural campaigns under extreme weather conditions (droughts)	**Supply** water **demanded**	Failure of supplying water demanded due to: **Water resources shortage** (Unavailability or insufficiency of water at sources to fulfil demand)	**Abnormal low precipitation / Low inflows to reservoirs**	**WATER SOURCES** (Level of water storage in reservoirs)	**Water resources availability at Maranhão and Montargil** (level of storage)	- Low Precipitation intensity - Temperature increase (> Evaporation)	- Storage capacity of Maranhão and Maranhão; - Planned upstream irrigation project (Crato dam), resulting in inflows reduction to Montargil; - Infrastructures conditions (level of leakages in reservoirs and transportation systems) - Limitaions of the existing remote surveilance and control system	(+) (-)	- Water resources concessions managed by Irrigators Association - ABRVS (water competition is mainly among farmers with no other significant competing uses); - Possibility of unfavourable changes of water resources concession rules; - WRM by ARBVS practices (e.g. compatibilization of electricity production with irrigation, reuse of surplus runoff; etc.); - ARBVS Preparedness (e.g. existence of apportioning strategies)	(+) (-) (+) (+) (+)
						Demand	Affecting SOIL moisture: - Temperature; - Precipitation during agricultural campaigns: intensity, distribution - Soil quality (water retention capacity)	- Access to water;	(+)	Ministry of Agriculture policy of implementation and granting of collective Public Irrigation Perimeters	(+)
								- Adequacy, efficiency and conditions of irrigation Infrastructures of farmers	(+/-)	High Farmers' technical capabilities due to: - Existence of specialized technical support services (e.g. COTR; Farmers Associations); - Divulgation of good practices based on the National Programme for the Efficient Use of Water (PNUEA - Agriculture)	(+) (+)
										Financing: - Farmers self-financing capacity; - Existence of EU financing support programmes (Rural Develop.); - National financing support orientations for EU funding application; - Change of support policy between EU financing programmes and uncertainty about the next cycle.	(+/-) (+) (+/-) (-)
								Type of cultures (irrigation requirements)	(+/-)	- Farmer's adaptive capacity (capacity to cultivate less demanding cultures during droughts); - Adequacy and efficiency of irrigation and other agricultural practices to the type of culture; - Belonging to Production Organizations;	(+) (+) (+)
										- CAP policies: i) Changes and uncertainty of financing support policy on each EU program . ii) Crops eligible for subsides are independent of geographic region (geo-climatic; soils being subjected to tide influence, etc.), not always favouring adequate crop selection; iii) setting of crops quota do not favour the selection of some crops (e.g. soy, beet)	(+/-)
		Supply water **in due timing**	**Delay in water supply**	**Inefficient transportation operationally**	**Transportation network**	**Operability**		- Transport in open channels; - Gates, valves and transportation network conditions; - Limitations of the existing remote surveillance and control system	(-) (-)	- Hydraulic and technical operational skills of ARBVS (Travel time estimation from reservoir to destination through transportation open channel, timely operation, etc. ...)	(+)
	Preserve the integrity and operability of infrastructures	Achieve low levels of **water losses**	**Failure to achieve water losses level required by the PNUEA - Agriculture** (National Programme for the Efficient Use of Water)	**Financial resources shortage**	**Reservoirs and Transportation network**	**Infrastructures**	Deterioration by aging	- Deficient condition of infrastructures		- Maintenance and rehabilitation tecnical capacity - Ability to allocate resources for maintenance and rehabilitation	

7.3.2.2. Lezíria Grande de Vila Franca de Xira

Hazard profile – LGVFX

Two main hazards can affect the Lezíria Grande PIP: the salinity of the water in the Conchoso water intake, that can limit the availability of water resources with quality for irrigation; and the water level in the Tagus estuary and surrounding rivers that can cause dykes overflow and inland inundation, affecting the integrity of the agricultural lands.

Water resources availability

During very dry periods, the Lezíria Grande PIP main water supply, located at Conchoso close the salinity propagation limit in the Tagus estuary, can reach concentrations that are inadequate for the crops (above 1). The negative impacts on the agriculture, including the loss of crops, and in the local economy are relevant, because the water scarcity usually starts in July, during the agricultural season. The most recent droughts, of 2005 and 2012, affected the agricultural activities in the Lezíria and several emergency measures to minimize the negative impacts were undertaken. During the 2012 drought, the measures included the exclusive use of the Risco river water intake and the construction of a weir in the Sorraia River. Recent improvements were made to increase the resilience to droughts, including the installation of a pumping system at the Conchoso water intake, allowing the pumping of the water from the Tagus River during low tide, and the construction of a removable weir in the Risco river.

Integrity of agricultural lands

The Lezíria Grande PIP can be affected by flooding episodes as a consequence of high water discharges in the Tagus and Sorraia rivers, and/or due to estuarine high water levels forced by tides and storm surges. The former affects mostly the northern sector of the Lezíria, and the latter in the southern area (Rodrigues et al., 2016) (Figure 7.6). The windstorm of February 15, 1941, considered one of the five most severe wind storms that occurred in Europe in the 20th century, had extensively affected the Tagus estuarine margin with relevant physical damages, human and economic losses (Freire et al., 2016; Fortunato, et al, 2017). Damages in the dykes and their overtopping leading to agriculture land flooding are the main consequences of the more recent inundation episodes, as the one that occurred on February 2010. Since it occurred out of the active farm season, only a restricted number of people and cattle had to be evacuated and no crops were lost. After the event the dykes were repaired and in some places reinforced and elevated.

Figure 7.6: Most affected areas during past flood events of riverine origin (in blue) and estuarine origin (in green). The area affected by the February 2010 flood event is marked in red. Background image from ESRI basemap (Rodrigues *et al*., 2016)

***Hazard, risk sources and risk factors* – LGVFX**

The risk sources and factors related to the Lezíria Grande PIP objectives are identified in Table 7.6.

Table 7.6: Hazard, risk sources and risk factors affecting LGVFX objectives

RISK OWNER	Risk Category: SCOPES	Risk Category: SPECIFIC OBJECTIVES	HAZARD	Risk SOURCES: HAZARD source(s)	Risk SOURCES: ELEMENTS at risk (Exposure/ hazard characteristics)	Risk FACTORS (Affecting Hazard likelihood or Consequences/Impacts (on elements at risk)): Related to:	Natural: Environmental	Man-induced: Physical		Man-induced: Human	
IRRIGATORS ASSOCIATIONS: ABLGVFX	**Assure supply of water quality during agricultural campaigns** under extreme weather conditions (droughts) (Fulfil needs and expectations of associated and beneficiary farmers)	Supply water with **quality**	**Salinity**	- Low river Tagus flow; - Sea level rise	WATER SOURCES (Conchoso)	Water resources quality at Conchoso in Tagus river	- Low river flow - Salt water intrusion - Sea level rise	Water supply infraestructures, storage and distribution condictions	(+)	WRM practices, including: volumes discharged to PT during exceptional meteorological conditions; EDP hydropower production regime	(+)
										Farmer's adaptive capacity, as adequacy and efficiency of irrigation and other agricultural practices to the type of culture	(+)
										Increasing emergency planning and response capability (e.g. forecast capability, warning systems)	(+)
IRRIGATORS ASSOCIATIONS: ABLGVFX	**Assure the protection of agricultural land** (Fulfil needs and expectations of beneficiary farmers)	**Avoid inundation** of agricultural lands and preserve the integrity and operability of the protection and water supply infraestructures	**Water level**	tides, high river flow, mean sea level, storm surges	dykes, agricultural land, access infrastructures	agricultural sector	tides, storm surges, high river flows, sea level rise, changes in storminess, increases in precipitation	Dykes conditions and characteristics	(+)	flood adaptation measures (e.g raising dykes height, changing land use), increasing emergency planning and response capability (e.g. forecast capability, warning systems)	(+)

7.3.2.3. Lezíria do Tejo

Hazard profile – Leziria do Tejo

As previously mentioned the majority of farmers from Lezíria do Vale do Tejo (LVT) do not benefit from public irrigation infrastructures. Groundwater is their main water source, either from Aluviões do Tejo or from Tejo/ Sado aquifers. The former is a very superficial water body, reacting very quickly to the Tagus river flow (days). Tejo/ Sado aquifers, due to their dimensions, have significant storage capacity providing inter-annual regulation.

Farmers share groundwater resources with public water supply utilities, Santarém and Azambuja in the right margin and Ribatejo and Golegã in the left margin. In dry rainy years, abstractions from groundwater increase. In Aluviões do Tejo impact is felt very quickly. Is Sado/ Tejo aquifer impact in the piezometric levels is only evident one year later. In a second or third consecutive year of reduced precipitation (under average) competition for uses is noticed.

Some farmers withdraw directly from the river Tagus and some benefit from “Vala do Tejo”, a public irrigation channel fed directly by Tagus flow by gravity. These farmers are totally dependent of Tagus flow. 1992; 1993; 2004, 2005, 2009, 2012 and 2016 were dry years affecting farmers dependent on superficial resources in lower Tagus basin.

***Hazard, risk sources and risk factors* – Leziria do Vale do Tejo**

Water resources management affects directly the superficial and groundwater availabilities. Issues related with superficial water resources in Lezíria do Tejo (TVT) are similar of those of Lezíria Grande de Vila Franca de Xira (LGFVX). LVT farmers have the advantage of being less often subjected to salt water intrusion, due to an upstream location. Also have the advantage of being able of groundwater.

LGVFX, being very close to Tagus estuary strongly recent from salt water intrusion. On the other hand, as the existing groundwater resources are EPAL strategic reserves, they cannot use groundwater to complement irrigation requirements.

LVT as the main disadvantage of do not benefit from collective irrigation infrastructures. Step 1 of risk identification is presented in Table 7.7. As risk analysis is not going to be performed for this group of farmers, events were not listed.

Table 7.7: Hazard, risk sources and risk factors affecting Farmers of LVT objectives

RISK OWNER	Risk Category: SCOPES	Risk Category: SPECIFIC OBJECTIVES	HAZARD	Risk SOURCES: HAZARD source(s)		Risk SOURCES: ELEMENTS at risk (Exposure/ hazard characteristics)	Risk FACTORS Affecting Hazard likelihood or Consequences/Impacts (on elements at risk): Natural: Environmental	Man-induced: Physical		Man-induced: Human (Water Resources Management)	
FARMERS of Lezíria do Vale do Tejo	**Analyse water resources governance impacts in agriculture in Lezíria do Vale do Tejo**	**Identify the water resources governance policies and practices that may affect irrigation** during agricultural campaigns under extreme weather conditions (droughts)	**Water resources shortage for agriculture in "Lezíria do Tejo"**	**Water Resources Management (WRM) policies and practices**	**WATER SOURCES**	**Superficial water sources for irrigation** (Tagus flow: quantity and regime during agricultural campaigns)	Modified River flow Salt water intrusion in lower Tagus Temperature	*Tagus Flows:* - Spain regime of flows released to Portugal:; - Hydropower production induced Tagus flows, due to upstream reservoirs' exploitation regimes (C. Bode and Belver) and Spanish inflows; *Storage Infrastructures:* - Limited Portuguese Tagus reservoirs capacity to regulate Spanish discharges; - Lack of storage capacity (reservoirs) in the basin oriented for agriculture; *Irrigation Infrastructures:* - Degradation of "Vala Real" (Tagus derivation open channel with more than 100 years) - Lack of collective irrigation networks	(-) (-) (-) (-) (-) (-)	*WRM practices:* - Spanish - Portuguese reservoirs convention / Bilateral regime of basins water resources sharing . E.g.: . agreed volumes and discharges regimes to PT; . decrease of volumes discharged to PT during exceptional meteorological conditions - EDP hydropower production regime based on internal factors (market, peaks, alternative production sources) not favouring other Tagus river users; - Lack of a clear and transparent water uses policy, mainly water allocation principles and licensing rules; - Lack of clear and transparent water competing uses allocation rules and principles during droughts (besides "rule" of 2 years water volume allocation in reservoirs for public water supply); - Lack of an integrated and realistic national strategy for climate change adaptation; - Lack of clear definition of responsibilities concerning the public hydric domain - Complex legal framework - Lack of Implementation of an updated national/Tagus basin Irrigation Plan	(-)
						Groundwater sources for irrigation (Availability)	Aquifer dimension and response behaviour; Soil characteristics (infiltration capacity)	Land cover		*WRM practices:* - Lack of knowledge about volumes abstracted; - Lack of knowledge about quantitative impact in the water bodies of each abstraction; - Lack of knowledge about timely quantitative status evolution; - Lack of a clear and transparent water uses policy, mainly water allocation principles and licensing rules; - Lack of clear and transparent water competing uses allocation rules and principles during droughts; - Lack of supervision of illegal abstractions and of contaminant discharges.	(-)

7.3.3 *Events*

7.3.3.1. Sorraia Valley

A set of plausible events and expected consequences is presented in Table 7.8, concerning the two main hazards in the Lezíria Grande PIP.

7.3.3.1. Lezíria Grande de Vila Franca de Xira (LGVFX)

A set of plausible events and expected consequences is presented in Table 7.9 and Table 7.10,concerning the two main hazards in the Lezíria Grande PIP.

Table 7.8: Events design for ARBVS

Event	EVENTS					
	CAUSES (set of Hazard Sources)	EVENT description		CONSEQUENCES		
		HAZARD pathways	ELEMENTS Impacted Water sources	on ARBVS' RMP objectives of <u>Suppling water demanded</u>	On Farmers	Agro industry; Local communities
1	Low precipitation during **ONE** hydrologic year	Reduced inflow to Montargil and Maranhão reservoirs + surplus from the previous year → storage at full capacity	Storage > average demand	Supply/ demand = 100%	none	none
2	Abnormal low precipitation during **TWO** consecutive hydrologic years	Reduced inflow to Montargil and Maranhão → sufficient storage to fulfil **average** demand	Storage ≈ average demand	Supply/ demand = 100%	none	none
3	Abnormal low precipitation during **TWO** consecutive hydrologic years	Reduced inflow to Montargil and Maranhão + 30% of total storage capacity requested for PWS → insufficient storage to fulfil **average** demand	Storage < average demand	Supply/ demand = 80%	**Permanent cultures:** none **Annual cultures:** Limited economic losses	none
4	Abnormal low precipitation during **THREE** consecutive hydrologic years	Reduced inflow to Montargil and Maranhão → insufficient storage to fulfil **average** demand	Storage < average demand	Supply/ demand = 60%	**Permanent cultures:** none **Annual cultures:** economic losses;; Loss of End-buyers Contracts	none
5	Abnormal low precipitation during **THREE** consecutive hydrologic years	Reduced inflow to Montargil and Maranhão → insufficient storage to fulfil **average** demand	Storage < average demand	Supply/ demand = 40%	**Permanent cultures:** none **Annual cultures:** Significant economic losses	- Economic losses; - Unemployment;
6	Abnormal low precipitation during **THREE** consecutive hydrologic years	Reduced inflow to Montargil and Maranhão → insufficient storage to fulfil **average** demand	Storage < average demand	Supply/ demand = 15%	**Permanent cultures:** none **Annual cultures:** Significant economic losses	- Economic losses; - Unemployment; - Impoverishment
7	Abnormal low precipitation during **FOUR** consecutive hydrologic years	Reduced inflow to Montargil and Maranhão → insufficient storage to fulfil **average** demand	Storage < average demand	Supply/ demand = 10%	**Permanent cultures:** some economic losses **Annual cultures:** Significant economic losses; Loss of sustainability	- Economic losses; - Unemployment; - Impoverishment

Table 7.9: Events design for the LGVFX, concerning the water availability

Risk Management Objectives	EVENTS: CAUSES (set of Hazard Sources)	EVENT description: HAZARD pathways	EVENT description: ELEMENTS Impacted	CONSEQUENCES: On Farmers	CONSEQUENCES: on ABLGVFX's RMP objectives	CONSEQUENCES: Agro industry; Local communities
Assure supply of water quality during agricultural campaigns	Tagus flow (mean daily discharge) Q= July monthly average	• Water salinity at Conchoso (>1) during July • Water salinity at Risco river (>1) during July	Availability of adequate water for irrigation (S<1) to fulfil the daily demand	None	Reduction in water adequate for irrigation Increased energy consumption due to the need to pump water at low tide Economic losses	None
	Low river Tagus flow (mean daily discharge) Q= of the worse drought with available data	• Water salinity at Conchoso (>1) during July • Water salinity at Risco river (>1) during July	Availability of adequate water for irrigation (S<1) to fulfil the daily demand Agricultural land quality	Changes in the production (quantity and quality) Economic losses and related social impacts	Reduction in water adequate for irrigation Salinization of the land due to irrigation with salty water Increased energy consumption due to the need to pump water at low tide Economic losses	Reduction of agricultural production Impact in related trade and services Economic losses Social impacts Lower revenues and unemployment
	Low river Tagus flow (mean daily discharge) Q=8m^3/s	• Water salinity at Conchoso (>1) during July • Water salinity at Risco river (>1) during July	Availability of adequate water for irrigation (S<1) to fulfil the daily demand Agricultural land quality	Changes in the production (quantity and quality) Economic losses and related social impacts	Reduction in water adequate for irrigation Salinization of the land due to irrigation with salty water Increased energy consumption due to the need to pump water at low tide Economic losses	Reduction of agricultural production Impact in related trade and services Economic losses Social impacts Lower revenues and unemployment

Risk Management Objectives	EVENTS					
	CAUSES (set of Hazard Sources)	EVENT description		CONSEQUENCES		
		HAZARD pathways	ELEMENTS Impacted	On Farmers	on ABLGVFX's RMP objectives	Agro industry; Local communities
	Low river Tagus flow (mean daily discharge) Q=0m^3/s	• Water salinity at Conchoso (>1) during July • Water salinity at Risco river (>1) during July	Availability of adequate water for irrigation (S<1) to fulfil the daily demand Agricultural land quality	Changes in the production (quantity and quality) Economic losses and related social impacts	Reduction in water adequate for irrigation Salinization of the land due to irrigation with salty water Increased energy consumption due to the need to pump water at low tide Economic losses	Reduction of agricultural production Impact in related trade and services Economic losses Social impacts Lower revenues and unemployment
	Low river Tagus flow (mean daily discharge) Q= of the worse drought with available data and sea level rise	• Water salinity at Conchoso (>1) during July • Water salinity at Risco river (>1) during July	Availability of adequate water for irrigation (S<1) to fulfil the daily demand Agricultural land quality	Changes in the production (quantity and quality) Economic losses and related social impacts	Reduction in water adequate for irrigation Salinization of the land due to irrigation with salty water Increased energy consumption due to the need to pump water at low tide Economic losses	Reduction of agricultural production Impact in related trade and services Economic losses Social impacts Lower revenues and unemployment

Table 7.10: Events design for the ABLGVFX, concerning the integrity of agricultural lands

	EVENTS					
Risk Management Objectives	**CAUSES** (set of Hazard Sources)	**EVENT description**		**CONSEQUENCES**		
		HAZARD pathways	**ELEMENTS Impacted**	**on ABLGVFX's RMP objectives**	**On Farmers**	**Agro industry; Local communities**
Avoid dykes overtopping and inland inundation	Major storm surge	Water level promotes dyke overtopping? What is the inundated area?	Dykes, access facilities and support infrastructures, agricultural lands	Damages in dykes, access facilities and support infrastructures Loss of land Economic losses	Loss of land Economic losses	None
	Major storm surge and spring tide	Water level promotes dyke overtopping? What is the inundated area?	Dykes, access facilities and support infrastructures, agricultural lands	Damages in dykes, access facilities and support infrastructures Loss of land Economic losses	Loss of land Economic losses	None
	Major storm surge and sea level rise	Water level promotes dyke overtopping? What is the inundated area?	Dykes, access facilities and support infrastructures, agricultural lands	Damages in dykes, access facilities and support infrastructures Loss of land Economic losses	Loss of land Economic losses	None

7.4. People and property safety – hazard identification

Extension of the analysis

The BINGO objective is to perform flood analysis (likelihood and consequences) and risk evaluation in the Trancão river basin, including preparing a list of structural and non-structural adaptation measures.

Hazard profile

The Trancão river basin is located at the northern limits of Lisbon, covering an area of 279 km^2 heavily industrialized and densely populated. The Trancão River is 30 km long and flows into the Tagus estuary, near the upstream limit of the estuary. The climate is temperate with a dry summer season. The average annual rainfall is 836 mm.

From the 1960’s, the proximity to the metropolitan area of Lisbon led to the urban and industrial expansion in the Trancão river basin, with construction works occupying floodplains with potential for agricultural development and housing on steep and erodible hill slopes. Urban, agricultural and industrial effluents have been discharged into the Trancão River and its main tributaries, the Loures and Póvoa rivers, and dramatically modified the region. Since the 1990’s the situation has been reversed with a series of interventions, namely the construction of wastewater treatment plants, the improvement of the drainage system and the rehabilitation of the riverbanks in the Trancão river mouth.

The Trancão River and its tributaries are prone to rapid floods due to intense rainfalls, steep slopes in the river basin headwaters and the existence of extensive urbanized areas. These flash floods cause high rates of soil and bank erosion, supplying large volumes of sediments and debris that clog narrow cross-sections of the river Trancão tributaries, increasing the water levels upstream and the flood hazard. In the historical flood events of 1967 of 1983, extensive inundations were observed, with overtopping of levees, that caused human casualties and severe social and economic impacts in most of the basin, particularly in Póvoa River and Loures lowlands. More recently, flood events were recorded in 1996, 2008 and 2012.

Hazard, risk sources and risk factors

The potential for damage from floods in the Trancão river basin is mostly related to the rapid runoff response to intense rainfall events and the existence of roads and buildings constructed in flood-prone areas, and to constrain in the river channels. The risk sources and factors related to the Trancão inundations are identified in Table 7.11.

Table 7.11: Hazard, risk sources and risk factors affecting people safety and protection of properties and activities

Risk Category		HAZARD	Risk SOURCES		Risk FACTORS Affecting Hazard likelihood or Consequences/Impacts (on elements at risk)		
					Natural	Man-induced	
SCOPES	SPECIFIC OBJECTIVES		HAZARD source(s)	ELEMENTS at risk (Exposure/ hazard characteristics)	Environmental	Physical	Human
Pleople safety and protection of properties and activities	To **minimize flood risk** for people during floods and to **reduce economic damage** on properties and agricultural sectors	Water level Flow velocities	High river flows	People; Residential and commercial property; Infrastructures; Essencial services and equipments; agriculture, industrial; cultural assets and ecosystems; Landscape and natural values	Precipitation intensities a	Land-use; Infrastructure conditions and location; Technologies for monitoring, forecast and warning	Human reliability; behavioural factors; people physical vulnerability; Capacity to cope; preparedness and emergency planning; Economic factors: uninsured sector; dimension of business; Governance: policies in place to reduce risk, risk zoning and regulations

Events

Flood discharges for different return periods considering the historical data and the Climate Change projections will be modelled according to Table 7.12. These events intend to evaluate the effects of climate change in the consequences of flood inundation with the same return period, but also to distinguish impacts. Therefore, floods with a return period of 20, 100 and 1000 year, which are envisaged to have minor, medium and significant impacts in the number of people affected and on economic losses, are predicted to be modelled.

Table 7.12: Events design for the Trancão river floods, concerning people safety and protection of properties and activities

STEP 2					
Events		EVENT description		CAUSES	CONSEQUENCES
		HAZARD pathways	ELEMENTS Impacted		
Historical data	20 years Return Period Flood	River Trancão overland flooding/ Direct inundation of low-lying river margins/Overtopping or breaching of dykes	Afecting agricultural areas, low scale industries, residential and commercial properties, access to services, urban equipment; roads and infrastrutures	Strong velocity runoff and high water levels in Trancão River basin	Loss of life; damages; disruption of services; economic losses for several sectors; cultural losses
	100 years Return Period Flood				
	1000 years Return Period Flood				
AC Projections	20 years Return Period Flood				
	100 years Return Period Flood				
	1000 years Return Period Flood				

7.5. Summary and remarks

Concerning droughts, risk factors identified both for EPAL and farmers show that competition with the hydro-electric energy sector is a strong risk factor, as well as water resources management policies and practices that directly affect the superficial and groundwater availabilities for use in the public water supply and agriculture sectors.

Both sectors have evolved significantly in the last two decades. Although more efficiency can still be achieved at sectorial level, water resources management is pointed out as being presently one of the most relevant factors requiring improvement. This is an important conclusion valid for average meteorological conditions. Climate change adaptation will then be a step forward beyond average conditions.

8 RISK IDENTIFICATION AT BERGEN RESEARCH SITE

8.1. Brief research site introduction

The Norwegian research site, Bergen, is located on the rainy west coast of Norway. Due to heavy precipitation amounts, large volumes of stormwater are generated and transported in a combined sewer system, causing combined sewer overflows during heavy precipitation events. Furthermore, the drinking water supply system is reliant on the steady loads of precipitation due to relatively small surface water reservoirs, leaving it vulnerable to dry spells. Hence, the risk management objectives within BINGO are twofold, focusing on: 1) urban drainage management and extreme precipitation events, and 2) public water supply and dry spells.

8.2. Urban drainage management

8.2.1 Scopes and objectives of the RMP

Bergen is known for its high precipitation loads, and flooding and pollution from CSOs during extreme precipitation events is the main concern within the scopes of BINGO. Due to this, a full risk management process (RMP) will be performed for the urban drainage case.

The objectives of the RMP is to prepare the urban drainage system in a subarea of the city, the Damsgård area, to avoid flooding and CSO during extreme precipitation conditions.

The specific scopes of the RMP are categorized into those focused on (1) Protection of economic activities, (2) Protection of the environment, and (3) protection of reputation and image. In detail, the specific scopes are (Table 8.1):

- Protection of critical public infrastructure (1)
- Reduction of economic damages on private goods and properties (1)
- Avoid impact on aquatic leisure activities (1)
- Avoid impact on recreational activities at banksides (1)
- Avoid loss of production (1)
- Avoid pollution from flooded industrial sites (2)
- Avoid loss of trust in the municipality (3)

Table 8.1: Bergen RS. Objectives and scopes of the risk assessment process of Bergen Municipality

RISK OWNER	OBJECTIVES	SCOPES	SPECIFIC OBJECTIVES	RISK CRITERIA (function of)	Risk Treatment				
					Identification	Analysis	Evaluation	SITE specific	GOVERNANCE
BERGEN Municipality	Preparation of urban drainage systems to **avoid CSO during extreme precipitation conditions**	**Economic** (Protection of Economic activities)	**Protection of critical public infrastructure** (e.g. main roads and railways, hospitals, parts of supply systems for energy, drinking water, sanitation systems)	No. of items critical infrastructure flooded Costs for reparation of damages (Euros)	✓	✓	✓	**YES**	**no**
			Reduction of economic **damages on private goods and properties**	Costs for reparation of damages (Euros) (e.g. reimbursements made by insurance companies)					
			Avoid impact on **aquatic leisure activities**	EU standard for bathing CSO discharge					
			Avoid impact on **recreational activities at banksides**	Area of flooded fields					
			Avoid loss of production	Nr. of days/hrs production downtime caused by flooding					
		Protection of environment	**Avoid pollution** from flooded **industrial** sites (industrial sites esp. with dangerous materials)	EU standard					
		Reputation and image	Avoid **Loss of trust** in the municipality	Customer satisfaction Nr. of negative reports in media pr. Year					

8.2.2 Hazards, risk sources and risk factors

For each specific scope of the RMP, risk identification is performed. Hazard, hazard sources, risk factors affecting likelihood, elements at risk, and risk factors affecting consequence is identified according to the definitions given in Chapter 3 'Guidelines for risk identification for BINGO RMP' of this report and summarised in Table 8.12.

Table 8.2: Risk identification step 1 (urban drainage)

	Risk Category		
KOMM	SCOPES	SPECIFIC OBJECTIVES	RISK CRITERIA (function of)
BERGEN Municipality	**Economic** (Protection of Economic activities)	**Protection of critical public infrastructure** (e.g. main roads and railways, hospitals, parts of supply systems for energy, drinking water, sanitation systems)	No. of items critical infrastructure flooded Costs for reparation of damages (Euros)
		Reduction of economic **damages on private goods and properties**	Costs for reparation of damages (Euros) (e.g. reimbursements made by insurance companies)
		Avoid impact on **aquatic leisure activities**	EU standard for bathing CSO discharge
		Avoid impact on **recreational activities at banksides**	Area of flooded fields
		Avoid loss of production	Nr. of days/hrs production downtime caused by flooding
	Protection of environment	**Avoid pollution** from flooded **industrial** sites (industrial sites esp. with dangerous materials)	EU standard
	Reputation and image	Avoid **Loss of trust** in the municipality	- Customer satisfaction - Nr. of negative reports in media pr. Year

HAZARD	STEP 1			
	HAZARD		CONSEQUENCES	
	HAZARD source(s)	**Risk FACTORS Affecting Hazard likelihood**	**ELEMENTS at risk (Exposure)**	**Risk FACTORS Affecting Consequences**
Water height Runoff velocity	Extreme precipitation	Pipe dimensions Impermeable surfaces Condition of collection system	People Residential and commercial property Infrastructures Essential services	Social: Disability/age, Awareness Governmental: Preparedness Technological: Warning systems
Water height Runoff velocity	Extreme precipitation	Pipe dimensions Impermeable surfaces Condition of collection system Existence of check valve topography Component location	Residential and commercial property Infrastructures	Detection system Awareness
CSO activation Pollution	Extreme precipitation Water level in CSO	Pipe dimensions Impermeable surfaces Condition of collection system	Receiving water bodies (fjord)	Domestic sewerage (combined system) Warning systems
Erosion Pollution	Extreme precipitation Sea level rise	Condition and dimension of collection system Location (e.g. height from sea level to bankside)	People Residential and commercial property Infrastructures Essential services Cultural assets Ecosystems Landscape and natural values	Exposure time Human behaviour / awareness Infrastructure protection Infrastructure condition Component location Warning and detection systems
Water height Runoff velocity	Extreme precipitation	Pipe dimensions Impermeable surfaces Condition of collection system	Residential and commercial property Infrastructures Essential services	Production site location Production site protection Production site condition
- Water height - Runoff velocity	- Extreme precipitation	- Pipe dimensions - Impermeable surfaces - Condition of collection system	- Receiving water bodies - Ecosystems - Landscape and natural values	- Type of industry - Industrial site protection - Industrial site condition - Exposure time - Detection and warning systems
- People's perception of municipality	- Disruption of service continuity - Negative publicity	- Miscommunication - Reputation	- People - Government/municipality	Frequency of events

8.2.3 Events

Further in the risk identification process, a set of events are defined. The events are described by the hazard pathways leading up to the event, the elements impacted in occurrence of the event, the causes of the event to occur, and, at last, the consequences of the event occurring. Some events are replicated but differentiated by the season in which it occurs. This is because different hazard sources (causes) may be linked to different seasons and because some consequences are more severe or relevant in some seasons. The full set of events is given in Table 8.3.

Table 8.3: Risk identification step 2 (urban drainage)

Risk category		STEP 2			
Risk Management Objectives	ID	EVENT description		CAUSES (set of Hazard Sources)	CONSEQUENCES (on RMP objectives)
		HAZARD pathways	ELEMENTS Impacted		
Preparation of urban drainage systems to avoid CSO during extreme precipitation conditions	E1	Flooding of private properties due to insufficient sewers capacity and non-existing/disfunctional check valves	Households, basements, goods	Extreme precipitation	Economic losses
	E2	Flooding /stagnant water of streets and public areas due to insufficient sewers capacity, preventing passability	People, essential services	Extreme precipitation	economic losses, decreased mobility
	E3	Contamination of receiving water bodies by CSO activation **during winter**	Receiving water (fjord), ecosystem	Extreme precipitation, water level in CSO	Fail to meet EU standard for bathing
	E4	Contamination of receiving water bodies by CSO activation **during spring**	Receiving water (fjord), ecosystem	Extreme precipitation, water level in CSO, sediments in sewer system (due to cleaning of streets after snow)	Fail to meet EU standard for bathing
	E5	Contamination of receiving water bodies by CSO activation **during summer**	Receiving water (fjord), ecosystem, people	Extreme precipitation, water level in CSO	Fail to meet EU standard for bathing, disturbance of water related activities
	E6	Erosion and pollution of banksides due increased water levels and CSO activation	Banskides. People	Extreme precipitation, water level in CSO, sea level rise	Flooded fields, disturbance of recreational activities at banksides
	E7	Measures causing unforeseen changes in water course, leading to flooding of private properties downstream	Households, basements, goods	Extreme precipitation, upstream measures	economic loss
	E8	Measures causing unforeseen changes in water course, leading to flooding of streets and public areas downstream	People, essential services	Extreme precipitation, upstream measures	economic loss, decreased mobility
	E9	Intakes to the sewer system blocked by leaves, trash etc, due to low maintenance, causing flooding of **streets and public areas during fall**.	People, essential services	Precipitation, maintenance level	economic loss, decreased mobility
	E10	Intakes to the sewer system blocked by leaves, trash etc, due to low maintenance, causing flooding of **private properties during fall**.	Households, basements, goods	Precipitation, maintenance level	Economic losses

Risk category	STEP 2				
Risk Management Objectives	ID	EVENT description: HAZARD pathways	EVENT description: ELEMENTS Impacted	CAUSES (set of Hazard Sources)	CONSEQUENCES (on RMP objectives)
	E11	Intakes to the sewer system blocked by ice / banks of snow (from plowing), causing flooding of **streets and public areas during winter/early spring**.	People, essential services	Cold, snowy period followed by mild and wet weather (rainfall, snowmelt)	economic loss, decreased mobility
	E12	Intakes to the sewer system blocked by ice / banks of snow (from plowing) causing flooding of **private properties during winter/early**.	Households, basements, goods	Cold, snowy period followed by mild and wet weather (rainfall, snowmelt)	Economic losses

8.3. Public water supply

8.3.1 Scopes and objectives of the RMP

The public water supply (PWS) in Bergen is well functioning and service continuity is well preserved. However, due to a winter drought in 2009/2010 causing unusual low water levels, the BINGO objectives includes a risk assessment of PWS in a future perspective. A partial RMP, which comprise of risk identification and a general strategy (bundle of risk treatments), is to be developed. The risk identification step is described in the following section.

The overall objective of the PWS RMP is to

- *Assure sufficient raw water provision for drinking water supply in climate change scenarios*

Specifically, this means that the water supplier, the municipality of Bergen, aims to

- *Supply water in adequate quantity: meeting customer's need without compromising requirements to storage reserves*

The context and objectives (Table 8.4) of the PWS RMP are described in more detail in in BINGO report D4.1 (Rocha et al, 2017).

Table 8.4: Bergen RS. Objectives and scopes of the risk assessment processes of public water supply

RISK OWNER	OBJECTIVES	SCOPES	SPECIFIC OBJECTIVES	Risk Assessment extent: Identification	Risk Assessment extent: Analysis	Risk Assessment extent: Evaluation	Risk Treatment: SITE specific	Risk Treatment: GOVER NANCE
PUBLIC WATER SUPPLY	**Assure sufficient raw water provision for drinking water supply** ***in climate change scenarios***	**Service continuity:** Water provision for public water supply	To supply water in adequate **quantity**: meeting customers' need without compromising requirements to storage reserves	✓			General list of adaptation measures	Water resources governance

Hazard, hazard sources, risk factors affecting likelihood, elements at risk, and risk factors affecting consequence is identified in the same way that for the urban drainage case. The hazards that may disturb service continuity are low water levels in drinking water reservoir or water scarcity for human needs. This hazard may occur due to low inflow to reservoir and possibly in combination with high water demand.

The winter drought in 2009/2010 occurred due to cold weather, where precipitation fell as snow and little water from snowmelt entered the reservoirs. Thus, potential hazard sources are lack of rainfall, lack of snowmelt and/or high evapotranspiration depending on the season. For these hazard sources, the key risk factor affecting hazard likelihood is temperature.

On the withdrawal side, increased water demand may be a potential hazard source. Risk factors that may affect this are leakages in the distribution system and/or the population size.

Disturbances in service continuity will put the PWS and people at risk. A long-lasting drought will be more severe than a shorter one, and the consequences could be critical if vulnerable customers, e.g. hospitals, elderly, etc., are exposed.

The risk identification step is summarized in Table 8.5.

Table 8.5: Risk identification – Public sector supply

Risk Category		
RISK OWNER	SCOPES	SPECIFIC OBJECTIVES
PUBLIC WATER SUPPY	**Service continuity:** Water provision for public water supply	To supply water in adequate **quantity**: meeting customers' need without compromising requirements to storage reserves

STEP 1				
HAZARD	HAZARD		CONSEQUENCES	
	HAZARD source(s)	Risk FACTORS Affecting Hazard likelihood	ELEMENTS at risk (Exposure)	Risk FACTORS Affecting Consequences
- Low water levels in drinking water reservoirs - Water scarcity for human needs	- Lack of rainfall - Lack of snowmelt - Evaporation - Increased water demand	- Temperature - Storage capacity - Leakages in distribution system - Population size	- Public water supply - People	- Duration of event - Vulnerable customers

8.4. Summary and remarks

The risk identification for urban drainage management and public water supply for the Norwegian research site in BINGO, Bergen, has been performed in accordance with the guidelines provided in Chapter 3 'Guidelines for risk identification for BINGO RMP' of this report and in close collaboration between research partner NTNU and end-user Bergen K.

9 RISK IDENTIFICATION AT BADALONA RESEARCH SITE

9.1. Brief research site introduction

Badalona with a population of 215,634 inhabitants within its administrative limits on a land area of 22.2 km^2 (9,713 inhabit. /km^2) is located on the Northeast coast of Spain. The Mediterranean Sea and the mountain range of Serra de la Marina limit geographically the city (For detailed information read D3.1 “Characterization of the catchments and the water systems”).

The morphology of Badalona presents areas with high gradients (close to Serra de la Marina) and flat areas near to the Mediterranean Sea. These characteristics, added to the typically heavy Mediterranean rainfalls with high intensities and short duration, leave the city in a prone situation to be flooded. Moreover, the land of the municipality was strongly urbanized during the last decades. All these aspects facilitate urban flash floods in several critical areas with significant economic damages and high hazard conditions for pedestrian and vehicular circulation

The flat area close to the seafront, which is the most densely populated area in the city, presents a highest vulnerability in terms of people safety and vehicular circulation. On the other hand, in case of moderate and heavy storm events, combined sewer overflows (CSOs) occur generating significant impacts on the receiving water body (Mediterranean sea) in terms of people’s safety, indirect losses to specific urban sectors (tourism, leisure, fishery, etc.) and on the image and reputation of the stakeholders involved in the sewer system and beaches management.

In this framework, Badalona is the Spanish research site selected in BINGO project fully focused on urban drainage and specifically on the evaluation of the effects of CC on flooding and pollution of bathing waters related to combined sewer overflows (CSOs).

9.2. Urban drainage management

9.2.1 Scopes and objectives of the RMP

According the *Guidance on Implementation of BINGO WP4 – Assessment of impacts of extreme weather events* (Rocha et al., 2017)*. Establishing the context for the risk management process*, risk is defined as the probability of threat of a hazard occurring in a vulnerable area and that may be avoided or minimised through preventive actions.

The extent of RMP in Badalona involves the effects of CC on the functioning of the urban drainage system with special regard to (Table 9.1):

- Flash floods problems with consequences on:
    - People´s safety.
    - Direct and indirect economic impacts related to flooding
- CSOs spills and the related impacts on water quality of the receiving water body (Mediterranean sea) with direct consequences on:
    - People's safety
    - Reputation and image of stakeholders involved in the management of CSOs.
    - Economic impacts on the activities and services related to receiving water bodies and potential affected by CSOs.

Regarding flash floods, Badalona municipality, as responsible of the sewerage system, acts as main risk owner, although Catalan Water Agency (ACA) is responsible for the management of the ephemeral natural streams crossing the city. In the second case, Badalona municipality, Barcelona Metropolitan Area (AMB) and Aigües de Barcelona, as company in charge of sewer interceptor and WWTP management, play this role. In both cases, the extent of the RMP covers the three steps of CC risk assessment (risk identification, analysis and evaluation) and the risk treatment phase.

Table 9.1: Badalona RS - Objectives and scopes of the risk assessment processes of the Badalona City Council

RISK OWNER	OBJECTIVES	SCOPES	SPECIFIC OBJECTIVES	Risk Assessment extent			Risk Treatment	
				Identification	Analysis	Evaluation	SITE SPECIFIC	GOVERNANCE
Badalona Municipality	Preparation of urban drainage systems to reduce flash floods *during extreme precipitation events*	People safety	To minimize flood risk for people and vehicles during heavy storm events	✓	✓	✓	YES	no
		Economic (Protection of goods, properties and economic activities)	Reduction of direct and indirect economic damage on goods and properties					
	Preparation of urban drainage systems to reduce CSOs *during moderate and extreme precipitation events*	People safety	To minimize risk for people due to the contamination of bathing waters during and after moderate and heavy storm events	✓	✓	✓	YES	no
		Reputation and image	Avoid Loss of trust in the municipality					

RISK OWNER	OBJECTIVES	SCOPES	SPECIFIC OBJECTIVES	Risk Assessment extent			Risk Treatment	
				Identification	Analysis	Evaluation	SITE SPECIFIC	GOVERNANCE
		Economic (Protection of goods, properties and economic activities)	Reduction of economic impacts on tourism, fishing and leisure sectors due to CSOs					

For human (concerning people safety) and direct economic impacts, flood risk will be assessed in the same way (flood risk maps related to each specific scenario and return period will be obtained by combining hazard maps and vulnerability maps). Business interruption due to floods is considered as indirect damages that will be assessed by developing an econometric model based on direct damages and business activities within the study area.

On the other hand, when CSO spills occur, reputation of city councils and other stakeholders managing sewer system may be affected, and this may be considered as intangible impact when citizens lose the trust on these actors. The citizens feelings will be investigated by surveying a representative sample of people and a risk assessment due to intangible impacts will be carry out too.

9.2.2 *Hazards, risk sources and risk factors related to flooding*

Hazard profile and vulnerability components (risk components) for people safety

A consensus has been reached within the field of urban drainage and, specifically of flood risk management that **hazard for pedestrians** can be assessed taking into account two specific flow parameters: water depth and velocity. Time is generally not considered in this kind of flooding (pluvial and sewer flooding) due to the short duration of the events.

In the studies of Russo et al. (2009; 2013) and of Martínez-Gomariz et al. (2016a,b), the most common flows during urban storm events, with low flow depth and high velocities, were reproduced through a physical model in real scale. These tests aimed to establish general hazard levels (low, medium or high) for pedestrians when attempting a street crossing under various combinations of water depth and velocity. This hazard classification allows the determination of specific thresholds for the flood hazard characterization of pedestrians exposed to urban flooding. Hydrodynamic conditions which result in a low hazard posed to pedestrians should be allowed to occur in the urban environment while medium and high hazard conditions should be more carefully considered and mitigated if possible. Hazard maps for different return periods may be produced by transforming depth and velocity variables, stored as outputs in each cell from the hydrodynamic model, into hazard levels (Figure 9.1). In this way, hazard assessment includes severity and frequency of the potential hazardous events.

Figure 9.1: Example of a hazard map for Marbella Case Study (http://www.pearl-fp7.eu/casestudies/spain/) for 1 (left) and 100 (right) years of return period. The high hazard corresponds with the colour red, medium hazard with yellow colour and low hazard with green colour.

In order to assess the pedestrians' vulnerability (risk factors or vulnerability components), the methodology developed in CORFU project and reflected in D3.4 of that project (Hammond et al. 2014) will be followed. The Spanish National Institute of Statistics (Instituto Nacional de Estadística, INE) provides statistical data of current population per census districts that will be used in the assessment. The required information per census district is the total inhabitants, people density, people age and number of foreign people.

The next step on the methodology application is to set the thresholds that allow us to assess the vulnerability in each census area. Three thresholds will be defined according to the three indicators used (Table 9.2). First, the threshold for the people density was set using the medium density of the studied area of Badalona and the definition of the National Institute of Statistics of urban area defined as a group of minimum 10 houses in a distance less than 200 m. This factor represents the potential exposure of people.

Then, thresholds regarding the most vulnerable people will be defined. Particularly age and number of foreign people were used to describe the sensitivity of the receptor (in this case people). During severe floods the very young, frail and elderly may be at particular risk from loss of life, so critical age was considered as less than 15 years old and over 65. On the other hand, the number of foreign people was also considered due to their potential language problems to communicate with rescue teams and the possibility of lack of understanding of alert instructions in case of flooding events.

Within urban areas some buildings can been considered as critical, because either vulnerable people or a high concentration of people (which makes them more vulnerable), such as hospitals, churches, shopping centres or nursing homes. The final vulnerability level was achieved according to the formulations proposed in Table 9.3. All these building will be identified and the vulnerability of the corresponding census district influenced by them will be increased as Table 9.3 indicates. In this way vulnerability assessment included sensitivity and exposure of people potentially affected by flooding.

Table 9.2: Thresholds to assess human vulnerability according to different criteria.

Vulnerability index	C % people age < 15 or > 65 years old	F % of foreign people	D People density
1 (low)	≤ 33%	≤ 33%	≤ 10 houses/200m
2 (medium)	33% < X ≤ 50%	33% < X ≤ 50%	10 houses/200m <X≤ average density in BCN
3 (high)	> 50%	> 50%	> average density in BCN

Table 9.3: Formulation to compute the total vulnerability index.

Vulnerability level	Formulation
Low	(D+C+F)/3 < 1.5
Medium	1.5< (D+C+F)/3 < 2
High	(D+C+F)/3 > 2
In case a critical building is located within a census disctrict, a value of (0.5*#buildings) will be added to the average valued	

Following the criteria established above, the vulnerability map was produced per each census area involved in the research site (Figure 9.2).

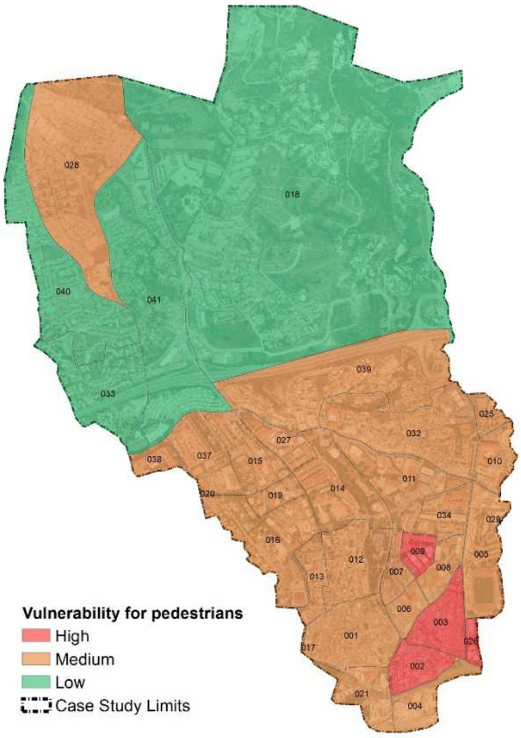


Figure 9.2: Example of vulnerability maps for Marbella per census districts

On the other hand, floods, especially in urban areas, can generate significant direct damages to **vehicles** themselves and to urban elements in case of loss of stability and collision, which cannot be neglected. When a vehicle is exposed to flooding, in case of losing stability, it becomes buoyant and may be washed away with potential injuries and fatalities. Therefore, the analysis of the stability of vehicles exposed to flooding is important in order to make decisions to reduce the damages and hazards. In the research of Martínez-Gomariz et al. (2016c,d), a new methodology to obtain the stability threshold for any real vehicle exposed to flooding was developed. This methodology enables to define a stable area in the domain flow depth-velocity with sufficient accuracy for any real vehicle. In this sense, a method is provided which decision-makers in the field of urban flood risk management can employ by defining a design vehicle and obtaining its corresponding stability threshold.

According to an article published in La Vanguardia (Spanish newspaper) on 3rd of September 2015, the two most sold vehicles in Spain are Citroen C4 (SC_{mod}: 5.90 $kg\cdot m^{-1}$), Seat Leon (SC_{mod}: 6.02 $kg\cdot m^{-1}$) and Seat Ibiza (SC_{mod}: 4.81 $kg\cdot m^{-1}$). Therefore the proposed vehicle for Badalona research site will be the Seat Ibiza model due its lowest SC_{mod} value, which was calculated considering a friction coefficient of 0.25. The Seat Ibiza model stability threshold, according to the methodology proposed by Martínez-Gomariz et al. (2016c), is $(v\cdot y)_{lower}$= 0.40 $m^2\cdot s^{-1}$ and presents a buoyancy depth of 28 cm. In order to define the hazard limits, a new $(v \cdot y)_{upper}$ value is proposed based on the maximum friction coefficient (μ=0.75) proposed in Gerard (2006). That friction coefficient value yields a SC_{mod}= 14.43 $kg \cdot m^{-1}$, and therefore an stability threshold $(v \cdot y)_{upper}$= 0.55 $m^2 \cdot s^{-1}$. Thus, the proposed limits for hazard delimitation are: Low Hazard below the product $(v \cdot y)$=0.40 $m^2 \cdot s^{-1}$, Medium Hazard for the values $(v \cdot y)$ compressed between 0.40 $m^2 \cdot s^{-1}$ and 0.55 $m^2 \cdot s^{-1}$, and High Hazard beyond $(v \cdot y)$=0.55 $m^2 \cdot s^{-1}$ (Figure 9.3). An analogous procedure could be conducted in order to select a representative vehicle in each site.

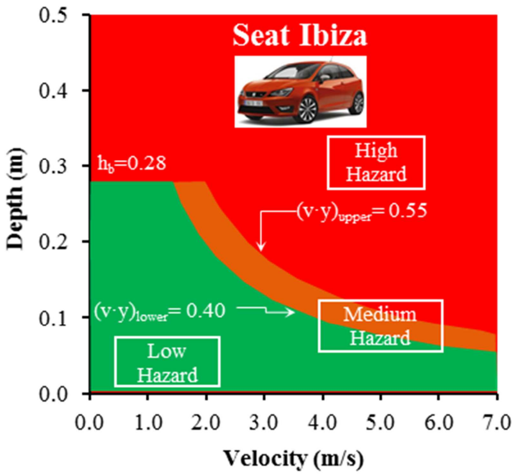


Figure 9.3: Hazards levels proposed for vehicles based on the results of Martínez-Gomariz et al. (2016c,d)

In order to assess the vehicles vulnerability, three levels will be proposed based on vehicular flow intensity of the different areas with road traffic. The more traffic flows the more vulnerable is this road. Table 9.4 indicates three vulnerability levels as an example. Ultimate limits will be defined further on.

Table 9.4: Vulnerability levels based on vehicular flow intensity

Vulnerability Level	Vehicular Flow Intensity (VFI)
Low	VFI < 5000
Medium	5000 ≥ VFI ≤ 10000
High	VFI > 10000

Following this criterion, a vulnerability map will be performed. Risk maps could be obtained crossing hazard and vulnerability risk maps for vehicles.

Hazard profile and vulnerability components (risk components) for goods and properties

Buildings are exposed at risk when an urban flood occurs. For the assessment of the direct damages three different types of data are required: land use information, flood maps and Depth Damage Curves (Figure 9.4). Land use information captures the type, morphology and use of the buildings in the study case area. Flood maps gather the information about hydraulic variables, namely water depths and velocities, and Depth Damage Curves are functions that relate the type of building and its characteristics with the depth of floods to account the damages produced by each flood event (economic risk assessment focused on direct damage).

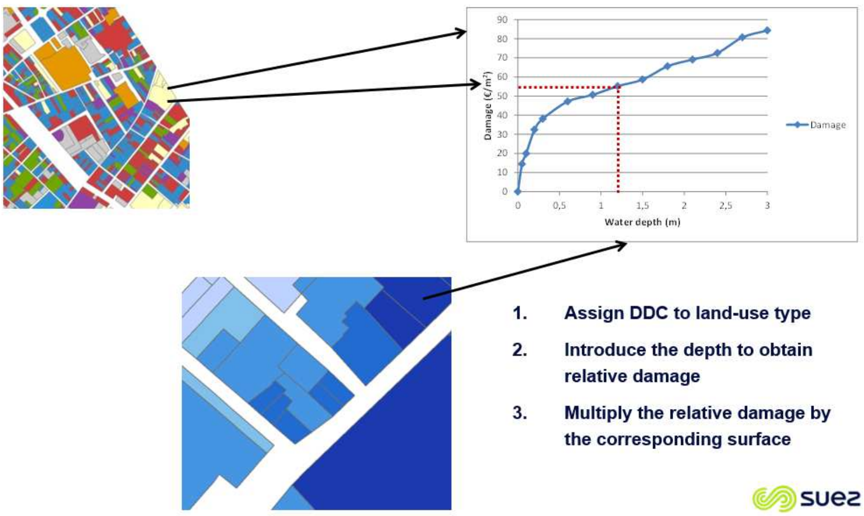


Figure 9.4: Procedure to apply depth-damage curves to buildings based on land uses and flood maps

In addition, indirect damages due to business interruption will be assessed. Those can be considered as a cascading effect of direct damages, as they try to assess how direct damages are spread across the closer economic agents. There are several existing methodologies to assess them, but while some of them are very data and resource demanding, others are not accurate enough. In this framework, a new methodology to assess indirect damages was considered necessary. In order to estimate indirect damages in the BINGO project for the Badalona research site, an econometric model will be developed which will relate indirect damages with direct damages, unemployment, dummies for the season of the year and dummies for the business activity.

On the other hand, **vehicles**, even if they do not reach the stability limit, will receive the impact of the flood, resulting in economic costs that cannot be neglected. This kind of assessment will be also carried out.

Finally, the expected annual damage (EAD) for direct tangible damages will be calculated (Velasco *et al.* 2015). EAD is the aggregation of the expected damage per each return period, taking into account the occurrence probability of each event. The result of the EAD will be used as an indicator of the magnitude of flooding events and as a useful tool to compare current state, with climate change and post-measures scenarios in order to take more informed decisions in urban planning.

9.2.3 Hazards, risk sources and risk factors related to CSO spills

The focus enforced by the Water Framework Directive (WFD, 2000/60/EC) is to consider the river basin as a single area of operation, in which hydraulic infrastructures have to be managed in an integrated manner, taking into account the condition of the receiving waters. In this sense, the commitment of the Urban Wastewater Treatment Directive (UWTD, 91/271/EC), the implementation of the WFD as well as the Bathing Waters Directive (BWD, 2006/7/EC) require the managers of urban drainage systems and WWTPs to work in a coordinated manner to reduce the pollution effects on receiving waters, especially in wet weather. Traditionally though, and still nowadays, these infrastructures have been designed and managed separately.

The development of the WFD implies also a higher level of protection for water bodies, enforcing to achieve a good ecological status of water ecosystems. To do so, the WFD sets the need to identify and evaluate the pressures and impacts affecting our aquatic environments. This analysis of pressures and impacts revealed, in the last decade, high levels of mobilized pollutants and high concentrations generated in sewer systems during wet weather and that directly affect receiving waters.

Combined urban drainage systems are designed to convey wastewater flows to treatment facilities in dry weather and for moderate rainfall events (usually up to 3-5 times the medium wastewater discharges), but as soon as these capacities are exceeded, water is by-passed to receiving bodies (rivers or sea) producing combined sewer overflows (CSOs) with different kinds of impacts identified in Table 9.6. Wastewater coming from houses as well as industrial sites or collective buildings (like hospitals) exhibit high concentrations of suspended solids, organic loads, nutrients, phosphorus, metals, faecal bacteria, etc. The recent progresses in quantification of micro-pollutants evidenced a high number of traced pollutants like pharmaceutical products, endocrine disruptors, metals, hormones or organic micropollutants. Similarly, the wash-off of natural (unpaved) and impervious areas like roads or roofs produce runoff flows with a high concentration of heavy metals (lead, zinc, etc. accumulated in dry weather), hydrocarbons and coarse debris (Gromaire et al. 2001, Chocat et al., 2007, Gasperi et al., 2008, Becouze et al., 2009). During wet weather, different kinds of impacts can be identified:

- Pollution related to the weirs of combined sewer systems, releasing to receiving waters a mix of storm-water and conventional wastewater (conveying the corresponding pollutants such as: bacteria, pathogens, industrial pollutants, oil and grease, nutrients, organic matter, solids, etc.)
- Overflows in WWTPs, when the treatment capacity is usually exceeded, so that the quality of the effluent is not as good as in dry weather operation.

  The effects of discharging highly polluted loads in the surface waters are hazardous for biological species, since a sudden decrease of dissolved oxygen affects their life ecological status, on the short term caused by a sudden input of nutrient and phosphorus materials, and on the long term by input of metals, organic micro-pollutants, etc.
- The possible use of waters for recreational activities (e.g. bathing water qualities), fishing, agricultural activities, production of drinking water, etc., may be affected.

Considering all these impacts and the still increasing development of urban areas, the management of storm-water flows and the reduction of CSOs has become a major stake for more and more European cities, from small to medium-sized and big sized cities. Legislation and standards are still mostly based on the number of emissions or overflows in many countries, so that the effects of varying pollutant loads on receiving waters is overlooked. It is clear thus that management of urban wastewater systems, especially during wet weather, is nowadays a challenge for managers and operators.

Badalona presents 5 km of beaches and during rain events, part of stormwater mixed with wastewater not entering into Wastewater Treatment Plants (WWTPs), generates CSO spills with significant social and economic damage related to the inability of bathing waters (Figure 9.5).

Figure 9.5: On the left consequences of flooding problems during one of the last heavy storm event. On the right, CSOs impact in Badalona bathing waters

In the framework of BINGO project **the impacts of CSOs will be analysed focusing on people safety, reputation and image for stakeholders involved in the sewer system and beaches management and, of course, economic damages**. Intangible damages will be covered by the two first, being **local and tourist bathers** the elements at risks (exposure). Some other intangible impacts may occur when citizens lose the trust in the stakeholders involved in the management of sewer system and bathing waters and beaches, since their reputation and image might be affected. A study about citizen's view in this regard (surveys) will be conducted by investigating how they would feel in case of different scenarios of CSOs, and how they felt in previous events. The number of days of non-compliance of the BWD (bathing forbidden and beaches closed) in a representative period (year or bathing season) will be considered as an indicator in this regard. Tangible damages will be address too, since CSO might affect different sectors, such as **tourism, fishing and leisure**, and those affections may be considered as indirect damages. All these indirect impacts will be analysed and a monetary assessment will be conducted. The assessment of future scenarios will allow to compare and define a degree of aggravation in order to propose and implement measures to reduce CSOs and thereby tangible and intangible impacts.

Another components of the vulnerability to take into account (beyond exposure) are the intrinsic characteristics of the system which would be, when it comes to CSO spills, the following: season of the discharge, climate variables affecting decaying micro-organism pollutant (wind, solar radiation, temperature, etc.), dry period previous to CSOs, and number of bathers.

Summary of hazard profiles, risk sources and risk factors identification

BINGO project focus on the urban drainage system. Moderate and extreme events are the main hazard considered. The hazard sources and risk factors related to Badalona Municipality objectives are identified in Table 9.5.

Table 9.5: Hazard, risk sources and risk factors affecting Badalona Municipality objectives

Risk Category				STEP 1			
				HAZARD		Vulnerability	
RISK OWNER	SCOPES	SPECIFIC OBJECTIVES	HAZARD	HAZARD source(s)	Risk FACTORS Affecting Hazard likelihood	ELEMENTS at risk (Exposure)	Intrinsic characteristics of the system (sensitivity, capacity to recover, etc.)
Badalona Municipality	People safety	To minimize flood risk for people and vehicles during heavy storm events	Flash flood	Extreme precipitation	Velocity and water depth	Pedestrians and vehicles	**Pedestrians**: Age, % of foreigners, population density, presence of critical buildings **Vehicles**: Vehicular Flow Intensity
	Protection of goods, properties and economic activities	Reduction of direct and indirects economic damage on goods and properties	Flash flood	Extreme precipitation	Water depth	Buildings and vehicles	Types of land uses. Buildings with or without basements and sealing capacity. Vehicular occupancy (amount of vehicles in a certain area) and types of vehicles.
	People safety	To minimize risk for people due to the contamination of bathing waters during and after moderate and heavy storm events	Discharges of CSOs	Combined Sewers Overflows to bathing areas due to precipitations (moderate and extreme)	Pollutant load	Bathers (tourists and locals)	Season of the discharge, climate variables affecting decaying micro-organism pollutant (wind, solar radiation, temperature, etc.), dry period previous to CSOs, number of Bathers.
	Reputation an image	Avoid Loss of trust in the municipality	Discharges of CSOs	Combined Sewers Overflows to bathing areas due to precipitations (moderate and extreme)	Frequency and duration of beach closures	Badalona Municipality	Season of the discharge, climate variables affecting decaying of micro-organism pollutant (wind, solar radiation, temperature, etc.), dry period previous to CSOs, number of Bathers.
	Protection of goods, properties and economic activities	Reduction of economic impacts on tourism, fishing and leisure sectors due to CSOs	Discharges of CSOs	Combined Sewers Overflows to bathing areas due to precipitations (moderate and extreme)	Frequency and duration of beach closures	Tourism, leisure and fishing sectors	Season of the discharge, climate variables affecting decaying micro-organism pollutant (wind, solar radiation, temperature, etc.), dry period previous to CSOs, number of Bathers.

9.2.4 Events

A set of plausible events and expected consequences is presented in Table 9.6. Regarding urban floods extreme events will be analysed and four return periods will be considered (1, 10, 100, 500 years).

CSOs can occur also for moderate events, so the concept of return period is not so adequate to describe their potential frequency of occurrence so, for the CSOs risk assessment, long-term series rainfall data will be considered (both annually and bathing-season period).

Table 9.6: Events design for Badalona Municipality

	EVENTS			
Risk Management Objectives	**CAUSES (set of Hazard Sources)**	**EVENT description**		**CONSEQUENCES (on RMP objectives)**
		HAZARD pathways	**Impacted ELEMENTS**	
People safety	Extreme precipitation	Sewer overflows from covers and direct run-off	Pedestrians	Personal injuries. Loss of life
Economic (Protection of goods, properties and economic activities)	Extreme precipitation	Sewer overflows from covers and direct run-off	Residential properties, commercial properties, cultural assets, urban equipment, vehicles.	Economic impact, cultural loss, damage to infrastructures and vehicles.
People safety	Discharges of Combined Sewers Overflows to bathing areas due to precipitations (moderate and extreme)	Water and beach contamination	Bathers and tourism	Environmental degradation, health problems and loss of life
Reputation and image	Discharges of Combined Sewers Overflows to bathing areas due to precipitations (moderate and extreme)	Water and beach contamination	Badalona municipality, cleaning services	Loss of reputation, economic impact.
Economic (Protection of goods, properties and economic activities)	Discharges of Combined Sewers Overflows to bathing areas due to precipitations (moderate and extreme)	Water and beach contamination	leisure and tourism business, and local fishing industry	Economic impact

9.3. Summary and remarks

The risk identification for urban drainage management to reduce flash floods and CSOs for Badalona research has been performed in accordance with the guidelines provided in Chapter 3 'Guidelines for risk identification for BINGO RMP' of this report.

On the basis of risk context described in D4.1 where scopes and risk owners of the case study were clearly defined, in this deliverable risk identification was carried out by the specification of hazard profiles, risk sources and risk factors of the two main objective of Badalona research site: flooding and CSOs reduction in a context of climate change.

Specifically, as a basis for the following task about risk analysis and risk assessment, hazard profile, risk sources and risk factors have been fully described providing some examples on hazard and vulnerability assessment.

10 SUMMARY OF THE RISK IDENTIFICATION PROCESS AT THE BINGO RESEARCH SITES

10.1. General overview of risk identification process at the BINGO RS

The objective of Work Package 4 (WP4) is to perform risk assessment for each BINGO research sites (RS). The purpose of Task 4.2 is to perform risk identification, the first step of the risk assessment process that is the ultimate objective to be achieved in Task 4.3 (Risk Analysis and Risk Evaluation).

In the first part of the document, general guidelines are provided in order to address risk identification process, while in the second part, the process followed in each BINGO research site has been described.

Due to the differences among the objectives and the scopes of the BINGO research sites, the procedures and the steps to achieve risk identification, risk analysis and risk assessment could vary significantly. Notwithstanding, risk identification is a common goal of all the research sites so, as far as possible, the contributions provided by local partners have followed a common structure where, after remembering the main characteristics of the sites, their scopes and objectives, risk identification has been clearly identified and described.

Although the categories of risks to be addressed in the BINGO RMP were already selected in Task 4.1 (the Context) and expressed into scopes and specific objectives, in this Deliverable, this information has been commonly structured, updated and presented in specific tables and sections. As summary, Table 10.1 includes the updated information for all BINGO research sites.

Table 10.1: Risk categories, main objectives and scope for the BINGO research sites.

Research site	Risk category	Main objective	Scope
Wupper River Basin (DE)	Drought and water scarcity	Provision of enough water	Service continuity of water provision
			Economic (avoid losses related to hydropower production)
			Maintenance of good reputation and image
			Protection of the environment ensuring ecological flow
	Fluvial flooding	Manage of water	Protection of environment

Research site	Risk category	Main objective	Scope
		resources for protection of goods and property protection and safeguard of population	People and property safety
			Economic (avoid losses)
			Reputation and image
Veluwe (NL)	Drought and water scarcity	Sustainable urban water management	Provide water resources for public water supply
			Protect and improve the natural landscape and cultural heritage qualities through sustainable groundwater management
			Provide sufficient volumes of groundwater for the maintenance of surface waters (waterstreams)
		Assure efficient production of drinking water	Service continuity: Water provision for public water supply and for other consumers (industry)
			Protect reputation of Vitens
Troodos (CY)	Drought and water scarcity	Domestic water supply	Continuity of water supply
		Agricultural water supply	Ensure fair, efficient and sustainable management of irrigation water supply in Peristerona
			Efficient management, conservation and exploitation of the Public Irrigation Infrastructures
Tagus River (PT)	Drought and water scarcity	Assure efficient production of drinking water	Continuity of water production
			Profitability
			Image
	Drought and water scarcity	Assure efficient management, conservation and exploitation of the public irrigation infrastructures of the Sorraia Valley	Assure supply of agricultural water demand
			Preserve the integrity and operability of infrastructures achieving low levels of water losses
		Assure efficient management, conservation and exploitation of the public irrigation infrastructures of Lezíria Grande de Vila Franca de Xira	Assure supply of agricultural water demand
			Preserve the integrity and operability of infrastructures
		Strengthen the agriculture economic sector in Lezíria do Vale do Tejo	Analyse water resources governance impacts in agriculture in Lezíria do Vale do Tejo
	River flooding	Assure efficient management, conservation and exploitation of the public irrigation infrastructures of Lezíria Grande de Vila Franca de Xira	Preserve the integrity of agricultural lands during flooding

Research site	Risk category	Main objective	Scope
Trancão River (PT)	River flooding	Flooding reduction	People safety and protection of properties activities
Bergen (NO)	Pluvial flooding	Preparation of urban drainage systems to reduce flooding and CSO during extreme precipitation conditions	Economic (Protection of economic activities)
			Protection of environment
			Reputation and image
	Drought and water scarcity	Assure sufficient raw water provision for drinking water supply	Water supply service continuity
Badalona (SP)	Pluvial flooding	Preparation of urban drainage systems to reduce flash floods	People safety
			Economic (Protection of goods, properties and economic activities)
		Preparation of urban drainage systems to reduce CSO	People safety
			Reputation and image
			Economic (Protection of goods, properties and economic activities)

As it was presented in deliverable D4.1 ”Context for risk assessment at the six research sites including criteria to be used in risk assessment”, most of the sites focuses on problems of water shortage and its impacts on water demand activities (Bergen, Tagus, Troodos, Wupper river basin and Veluwe). Southern sites also focus on the consequences of intense precipitation and floods (Badalona, Tagus and Troodos).

In terms of water shortage, the common natural hazard source is, generally, the reduction of water availability (surface and groundwater resources) due to the abnormal reduction of precipitation (or snow in Bergen) and increase of evaporation rates.

In parallel with the reduction of disposable fresh water, other hazard sources have been identified like:

- An increase of demand for fresh water to combat salinization (Veluwe), for irrigation, for industrial cooling and water supply (increase of population and leisure activities).
- Old water supply infrastructures (presence of algae and bacteria in supply pipelines, leakages...)
- Obsolete water resources management and practices (financial shortages for improvements).

Moreover, extended low precipitation generates reduction of surfaces flows within catchments and a consequent reduction of groundwater recharge. This phenomena lead to a reduction of storage capacity and a deterioration of water quality with negative impacts on water supply sector in terms of economic, financial losses and environmental deterioration.

Regarding flood events, the common natural hazard source are the intense precipitations that can produce the increase of river flows and runoff from surfaces (pluvial and river flooding). These events can lead into the increase of water depths and velocities and affect the:

- Safety of people
- Residential and commercial properties structures
- Agricultural land productions
- Operation of reservoirs, dykes, transport or other water production infrastructures.

Heavy and moderate storm events can also produce CSOs with significant deterioration of water quality of receiving water bodies with important tangible and intangible impacts (Bergen and Badalona).

The context (D4.1) and the risk factors identified in this step will be the basis of vulnerability assessment to be performed in risk analysis (D4.3). In fact, as a basis for the following task about risk analysis and risk assessment, hazard profile, risk sources and risk factors have been fully described in specific tables for all the sites and each specific objective. Moreover, in some cases (Tagus and Badalona), information about and examples of hazard and vulnerability assessment have already been provided.

Due to the similarity among some risk scopes, a common framework for the risk analysis and evaluation will be established in the Task 4.3 and also applied in WP5 for the risk treatment. In fact, Task 4.2 has shown potential synergies due to the common characteristics of the exposed elements (people, properties) and services respect to drought and flooding in a context of climate change. These links will allow to apply state of the art methodologies and common criteria and frameworks to perform hazard, vulnerability and risk assessment in several research sites in order to demonstrate the replicability of BINGO outputs to better understand the potential impacts produced by extreme weather events concerning droughts and floods.

10.2. Conclusions and recommendations

The main purpose of this report is to present the results of the risk identification (Deliverable D4.2) for all risk management processes of each BINGO research sites. A general framework was provided as well guidelines to perform the two steps for risk identification, envisaging already risk analysis and risk evaluation, i.e., the completion of risk assessment. Relevant hazards, risk sources and risk factors were identified, in a first step, and events (identifying general causes and consequences) were specified, in a second step, for all the Research Sites ‘activities and sectors.

In fact, the specification of the events is presented within this report but further in-depth analyses are due for risk analysis (deliverable D4.3). The latter are expected to be carried out in the next coming months, as they are necessary for modelling and to allow the hazard likelihood estimation. The detail of risk analysis in the BINGO research sites will depend on the site conditions and resources, on the data availability and also on the background and knowledge of BINGO teams involved in each research site as well as on stakeholder’s engagement.

11 BIBLIOGRAPHY

ALEKSANDROVA, M.; GAIN, Animesh K. and GIUPPON C. (2016) - **Assessing agricultural systems vulnerability to climate change to inform adaptation planning: an application in Khorezm, Uzbekistan**. Mitig Adapt Strateg Glob Change (2016) 21:1263–1287. DOI 10.1007/s11027-015-9655-y

Becouze C., Bertrand-Krajewski J.-L., Dembélé A., Cren-Olivé C., Coquery M. (2009). **Preliminary assessment of fluxes of priority pollutants in stormwater discharges in two urban catchments in Lyon, France**. Proceedings of the 13th IWA international conference on Diffuse Pollution and Integrated Watershed Management, Seoul, South Korea.

BEEK T., VAN ALPHEN E.-J., ALVES E., BRUGGEMAN A., CAMERA A., FOHRMANN H., FORTUNATO A., FREIRE P., IACOVIDES A., IACOVIDES I., KRISTVIK, KÜBECK C., LORZA P., MUTHANNA T., NOVO E., ROCHA F., RODRIGUES M., RODRIGUES R., RUSSO B., SÁNCHEZ P., SCHEIBEL M., SPEK T., WITTE F., ZOUMIDES C.(2016). **Characterization of the catchments and water systems**. Deliverable 3.1. BINGO - Bringing innovation to ongoing water management – a better future under climate change assessment.

BRUGGEMAN, A., ZOUMIDES, C., CAMERA, C. (2015). **The effect of climate change on crop production in Cyprus** – The Cyprus green-blue water model and scenario modelling. AGWATER Scientific Report 8. The Cyprus Institute, Nicosia, Cyprus.

CHOCAT B., BARRAUD S. et BERTRAND-KRAJEWSKI J.-L. (2007) **Les eaux pluviales urbaines et les rejets urbains de temps de pluie. Paris (France)**: Les Techniques de l'Ingénieur

CyStat (2014). **Census of agriculture 2010. Agricultural statistics, Series 1, Report No. 8**. Printing Office of the Republic of Cyprus, Nicosia, Cyprus.

FORTUNATO, A. B; FREIRE, P.; BERTIN, X.; RODRIGUES, M.; FERREIRA, J.; LIBERATO, M. L. (2017). **A numerical study of the February 15, 1941 storm in the Tagus estuary**, Continental Shelf Research 144, 50 - 64. doi: 10.1016/j.csr.2017.06.023

FREIRE, P.; TAVARES, A.O.; SÁ, L.; OLIVEIRA, A.; FORTUNATO, A.B.; SANTOS, P.P.; RILO, A.; GOMES, J.L.; ROGEIRO, J.; PABLO, R.; PINTO, P.J. (2016). **A local-scale approach to estuarine flood risk management**, Natural Hazards 84, 3: 1705-1739. DOI: 10.1007/s11069-016-2510-y

GASPERI J., GARNAUD S., ROCHER V. and MOILLERON R. (2008). **Priority pollutants in wastewater and combined sewer overflow**. Science of the Total Environment, 407(1): 263-272.

GERARD, M. (2006). **Tire-road friction estimation using slip-based observers**. Master Thesis. Department of Automatic Control, Lund University, Sweden.

GROMAIRE M.C., GARNAUD S., SAAD M. and CHEBBO G. (2001). **Contribution of different sources to the pollution of wet weather flows in combined sewers**. Water Research

IACOVIDES A., MOUSKOUNDIS M., IACOVIDES I., RUSSO B., SÁNCHEZ P., MONTES J.A., SEIFU A., KRISTVIK E., LORZA P., SCHEIBEL M., RODRIGUES R., HENRIQUES M.J., ALVES E., RODRIGUES M., SPEK T., AUS DER BEEK T. (2016). - **Future Land and Water Use Scenarios.** Deliverable 3.2, BINGO - Bringing innovation to ongoing water management – a better future under climate change assessment.

ISO 31000:2009 **RISK MANAGEMENT—Principles and guidelines. International organization for standardization**, Geneva, Switzerland.

ISO GUIDE 73:2009 **RISK MANAGEMENT—Vocabulary. International organization for standardization**, Geneva, Switzerland.

ISO 31010:2009 **RISK MANAGEMENT— Risk assessment techniques. International organization for standardization**, Geneva, Switzerland.

MANRE (Ministry of Agriculture, Natural Resources and Environment) (2012**). Implementation of Article 10 of the Nitrates Directive (91/676 / EEC) for the protection of water resources from nitrates from agricultural sources** - Cyprus' National Report. Ministry of Agriculture, Natural Resources and the Environment, Nicosia. (in Greek)

MARTÍNEZ-GOMARIZ, E. (2016a). **Inundaciones urbanas: criterios de peligrosidad y evaluación del riesgo para peatones y vehículos** (Urban floods: hazard criteria and risk assessment for pedestrians and vehicles). PhD Thesis. Technical University of Catalonia, Barcelona, Spain.

MARTÍNEZ-GOMARIZ, E., GÓMEZ, M., RUSSO, B. (2016b). **Experimental study of the stability of pedestrians exposed to urban pluvial flooding**. Natural Hazards.

MARTÍNEZ-GOMARIZ, E., GÓMEZ, M., RUSSO, B. (2016c). **Stability criteria for flooded vehicles: A state of the art review**. Journal of Flood Risk Management. 10p

MEDERER, J.M., 2009. **Water resources and dynamics of the Troodos igneous aquifer-system, Cyprus**. Thesis (PhD). University of Wurzburg.

ROCHA, F. (2016). **Guidance on implementation of BINGO WP4 – Assessment of impacts of extreme weather events.** Establishing the context for the risk management process. Relatório 168/2016. DHA/NRE. LNEC, Lisboa, 2016.

ROCHA, F.; VISEU, T. (2017) **Guidance on implementation of BINGO WP4 – Assessment of impacts of extreme weather events.** Developing risk identification. BINGO - Bringing innovation to ongoing water management – a better future under climate change assessment.

ROCHA, F.; VISEU, T.; BARBOSA, A.E, (Coordination) *and* ALPHEN, H-J. VAN; ALVES, E.; BEEK, T AUS DER.; BRUGGEMAN, A.; FORTUNATO, A.; FREIRE, P.; GIANNAKIS, E.; GÖRLITZ, S.; HEIN, A.; IACOVIDES, A.; IACOVIDES, I.; INTERWIES, E.; KOTI, J.; LORZA, P.; MÄLZER, H.-J.; MARTÍNEZ, M.; MUTHANNA, T.; NOVO, E.; OLIVEIRA, M.; RODRIGUES, M.; RUSSO, B.; SÁNCHEZ, P.; SÆGROV, S.; SCHEIBEL, M.; SPEK, T.; SUNYER, D.; ZOUMIDES, C. (2017). **Context for risk assessment at the six research**

sites, including criteria to be used in risk assessment. Deliverable 4.1 (2nd version), BINGO - Bringing innovation to ongoing water management – a better future under climate change assessment.

RODRIGUES, M., FORTUNATO, A. B., FREIRE, P., ALVES, E. (2016). **Characterization of The Hydro-Agricultural Development of The Lezíria Grande de Vila Franca de Xira and of the Mouchão de Alhandra**, Report 169/2016 - DHA/NEC

RUSSO, B. (2009). **Design of surface drainage systems according to hazard criteria related to flooding of urban areas**. PhD Thesis. Technical University of Catalonia, Barcelona, Spain

RUSSO, B., GÓMEZ, M., MACCHIONE, F. (2013). **Pedestrian hazard criteria for flooded urban areas**. Nat Hazards 69:251–265. doi: 10.1007/s11069-013-0702-2.

VELASCO, M., CABELLO, A., RUSSO, B. (2015). **Flood damage assessment in urban areas. Application to the Raval district of Barcelona using synthetic depth damage curves**. Urban Water Journal. 13(4), 426-440.

ANNEXES

ANNEX I – BINGO RISK GLOSSARY: RISK IDENTIFICATION

NOTE:

1 - The basis of this GLOSSARY is ISO Guide 73:2009.

2 – Some terms and definitions were added. So far (24-sep-2015) their origin is the PREPARED Project.

3 – The column CLARIFICATION intends to develop further clarification to the definitions, in case doubts arise.

The International Standard (ISO 31000:2009) can be applied to any type of risk, whatever its nature, whether having positive or negative consequences. This International Standard (ISO 31000:2009) can be applied throughout the life of an organization, and to a wide range of activities, including strategies and decisions, operations, processes, functions, projects, products, services and assets.

ISO Guide 73:2009, defin. nº	Terms	Definitions	CLARIFICATION AND OTHER SOURCES
2.1.3	Risk management plan	Scheme within the **risk management framework** specifying the approach, the management components and resources to be applied to the **management of risk.** NOTE 1 Management components typically include procedures, practices, assignment of responsibilities, sequence and timing of activities. NOTE 2 The risk management plan can be applied to a particular product, process and project, and part or whole of the organization	
		3. RISK MANAGEMENT PROCESS	
3.1	**RISK MANAGEMENT PROCESS**	**Systematic application of management policies, procedures and practices to the activities of communicating, consulting, establishing the context, and identifying, analysing, evaluating, treating, monitoring and reviewing risk.**	
	Scope		Primary aim. (PREPARED Project) Example: Protection of public health or public safety; Protection of environment; of economic activities
3.2		**Communication and consultation**	
3.2.1	Communication and consultation	Continual and iterative processes that an organization conducts to provide, share or obtain information and to engage in dialogue with **stakeholders** regarding the management of **risk**. NOTE 1 The information can relate to the existence, nature, form, likelihood, significance, evaluation, acceptability and treatment of the management of risk. NOTE 2 Consultation is a two-way process of informed communication between an organization and its stakeholders on an issue prior to making a decision or determining a direction on that issue. Consultation is: - a process which impacts on a decision through influence rather than power; and - an input to decision making, not joint decision making.	
3.2.1.1	Stakeholder	Person or organization that can affect, be affected by, or perceive themselves to be affected by a decision or activity. NOTE A decision maker can be a stakeholder.	

3.2.1.2	Risk perception	View of stakeholder's on a risk, reflecting the needs, issues, knowledge, belief and values.	
ISO Guide 73:2009, defin. nº	**Terms**	**Definitions**	**CLARIFICATION AND OTHER SOURCES**
3.3		**CONTEXT:**	
3.3.1	ESTABLISHING THE CONTEXT	Defining the external and internal parameters to be taken into account when managing risk, and setting the scope and **risk criteria** for the **risk management policy**.	
3.3.1.1	External context	External environment in which the organization seeks to achieve its objectives. Can include: the cultural, social, political, legal, regulatory, financial, technological, economic, natural and competitive environment, whether international, national, regional or local; key drivers and trends having impact on the objectives of the organization; and relationships with, and perceptions and values of external **stakeholders.**	
3.3.1.2	Internal context	Internal environment in which the organization seeks to achieve its objectives. Include, but is not limited to: governance, organizational structure, roles and accountabilities; policies, objectives, and the strategies that are in place to achieve them; the capabilities, understood in terms of resources and knowledge (e.g. capital, time, people, processes, systems and technologies); information systems, information flows and decision-making processes (both formal and informal); relationships with, and perceptions and values of, internal stakeholders; the organization's culture; standards, guidelines and models adopted by the organization; and form and extent of contractual relationships.	
3.3.1.3	Risk criteria	Terms of reference against which the significance of a **risk** is evaluated. NOTE 1 Risk criteria are based on organizational objectives, and **external** and **internal** context. NOTE 2 Risk criteria can be derived from standards, laws, policies and	

		other requirements.	
ISO Guide 73:2009, defin. nº	Terms	Definitions	CLARIFICATION AND OTHER SOURCES
3.4		**RISK ASSESSMENT**	
3.4.1	RISK ASSESSMENT	Overall process of risk identification, risk analysis and risk evaluation.	
3.5		**RISK IDENTIFICATION**	
3.5.1	RISK IDENTIFICATION	Process of finding, recognizing and describing **risks.** NOTE 1 Risk identification involves the identification of risk **sources, events**, their causes and their potential consequences. NOTE 2 Risk identification can involve historical data, theoretical analysis, informed and expert opinions, and stakeholder's needs.	
3.5.1.2	Risk source	Element which alone or in combination has the intrinsic potential to give rise to **risk.** NOTE A risk source can be tangible or intangible	Risk source is where the hazardous event potentially begins. (PREPARED Project (Almeida *et al*., 2011a)
3.5.1.3	Event	Occurrence or change of a particular set of circumstances NOTE 1 An event can be one or more occurrences, and can have several causes. NOTE 2 An event can consist of something not happening. NOTE 3 An event can sometimes be referred to as an "incident" or "accident". NOTE 4 An event without consequences can also be referred to as a "near miss", "incident", "near hit" or "close call".	
3.5.1.4	Hazard	Source of potential harm. A hazard can be a risk source.	A dangerous phenomenon (substance, human activity or condition) that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage (MRC-CCAI, 2013). In the context of the BINGO risk assessment, the focus is on hydrological hazards, i.e. floods and droughts (sometimes, "climate change" is also described as a "hazard"; in the common understanding developed here, however, CC is regarded as a factor, a driver, exaggerating the effects of future hazards).

ISO Guide 73:2009, defin. nº	Terms	Definitions	CLARIFICATION AND OTHER SOURCES
	Hazardous event		An event which can cause harm, e.g. a situation that leads to the presence or release of a hazard (Beuken, 2008). The hazardous event is part of the event pathway (PREPARED Project (Almeida *et al.* , 2011a & 2013)
3.5.1.5	Risk owner	Person or entity with the accountability and authority to manage a **risk.**	
3.6		**RISK ANALYSIS**	
3.6.1	RISK ANALYSIS	Process to comprehend the nature of **risk** and to determine the **level of risk.** NOTE 1 Risk analysis provides the basis for risk evaluation (2.24) and decisions about risk treatment. NOTE 2 Risk analysis includes risk estimation.	
3.6.1.1	Likelihood	Chance of something happening. NOTE 1 In risk management terminology, the word “likelihood” is used to refer to the chance of something happening, whether defined, measured or determined objectively or subjectively, qualitatively or quantitatively, and described using general terms or mathematically (such as a probability or a frequency over a given time period). NOTE 2 The English term “likelihood” does not have a direct equivalent in some languages; instead, the equivalent of the term “probability” is often used. However, in English, “probability” is often narrowly interpreted as a mathematical term. Therefore, in risk management terminology, “likelihood” is used with the intent that it should have the same broad interpretation as the term “probability” has in many languages other than English.	Chance of something happening, whether defined, measured or determined objectively or subjectively, qualitatively or quantitatively, and described using general terms or mathematically such as a **probability** or a **frequency** over a given time period. Probability is the measure of the chance of occurrence expressed as a number between 0 and 1, where 0 is impossibility and 1 is absolute certainty. In some languages **probability** is used with the same broad meaning. (PREPARED Project Almeida *et al.*, 2013))
3.6.1.2	Exposure	Extent to which a system is subject to an **event** (ISO GUIDE 73/2009).	Refers to the inventory (and values) of elements that are present in areas in which hazardous events (floods or other) may occur and can be adversely affected (potentially damaged or disrupted) by those events. These values depend on the presence of people, livelihoods, species or ecosystems, environmental services and resources, infrastructure, or economic, social, cultural assets in places that could be adversely affected (IPCC, 2013)
ISO Guide	Terms	Definitions	CLARIFICATION AND OTHER

73:2009, defin. nº			SOURCES
3.6.1.3	Consequence	Outcome of an **event** affecting objectives. NOTE 1 An event can lead to a range of consequences. NOTE 2 A consequence can be certain or uncertain and can have positive or negative effects on objectives. NOTE 3 Consequences can be expressed qualitatively or quantitatively. NOTE 4 Initial consequences can escalate through knock-on effects.	Considered as the extent of harm, which can be expected under certain conditions of exposure, susceptibilities and resilience. The indicators for this component can be separated in two categories; the first one gives details on the general characteristics of the hazardous event and the second one covers the vulnerability of the different elements at risk.
3.6.1.4	Probability	Measure of the chance of occurrence expressed as a number between 0 and 1, where 0 is impossibility and 1 is absolute certainty. NOTE See definition 3.6.1.1, Note 2.	
3.6.1.5	Frequency	Number of **events** or outcomes per defined unit of time. NOTE Frequency can be applied to past events or to potential future events, where it can be used as a measure of likelihood / probability.	
3.6.1.6	Vulnerability	Intrinsic properties of something resulting in susceptibility to a risk source that can lead to an event with a consequence.	Vulnerability refers to the propensity or capacities of exposed elements (such as human beings, their livelihoods, and assets) that favour, either adversely or beneficially, the adverse effects of hazardous events. NOTE: Within BINGO vulnerability consists on exposure, susceptibility (or sensitivity) and resilience.
	Susceptibility		Susceptibility (within BINGO susceptibility and sensitivity, will act as synonyms) is the degree to which the system is affected, depending on the own intrinsic characteristics of its exposed elements within the area in which hazardous events may occur. These intrinsic properties include, for instance, the physical characteristics of exposed elements (infrastructures, buildings, etc.), the economic and social context of the community, etc. For floods, for instance, important capacities are the awareness and preparedness of affected people and the existence of mitigation measures to reduce the effects of the hazards, like warning systems and emergency plans.
ISO Guide 73:2009, defin. nº	Terms	Definitions	CLARIFICATION AND OTHER SOURCES

3.6.1.7	Risk matrix	Tool for ranking and displaying **risks** by defining ranges for **consequence** and **likelihood**	
3.6.1.8	Level of risk	Magnitude of a **risk** or combination of risks, expressed in terms of the combination of **consequences** and their **likelihood.**	
	Risk factor		Something that can have an effect on the risk level, by changing the probability or the consequences of an event. Risk factors are often causes or causal factors that can be acted upon using risk reduction measures. Typically three main categories are considered namely human factors, environmental factors and equipment/infrastructure factors. (PREPARED Project – Almeida *et al.*, 2011a &2013)
3.7		**RISK EVALUATION**	
3.7.1	RISK EVALUATION	Process of comparing the results of **risk analysis** with **risk criteria** to determine whether the **risk** and/or its magnitude is acceptable or tolerable. NOTE Risk evaluation assists in the decision about risk treatment.	
3.7.1.1	Risk attitude	Organization's approach to assess and eventually pursue, retain, take or turn away from risk.	
3.7.1.2	Risk appetite	Amount and type of **risk** (that an organization is willing to pursue or retain.	
3.7.1.3	Risk tolerance	Organization's or **stakeholder**'s readiness to bear the **risk** after **risk treatment** in order to achieve its objectives. NOTE Risk tolerance can be influenced by legal or regulatory requirements.	
3.7.1.4	Risk aversion	Attitude to turn away from **risk.**	
3.7.1.5	Risk aggregation	Combination of a number of risks into one **risk** to develop a more complete understanding of the overall risk.	
3.7.1.6	Risk acceptance	Informed decision to take a particular **risk.** NOTE 1 Risk acceptance can occur without **risk treatment** or during the process of risk treatment. NOTE 2 Accepted risks are subject to **monitoring** a**nd** **review.**	
ISO Guide 73:2009, defin. nº	**Terms**	**Definitions**	**CLARIFICATION AND OTHER SOURCES**
3.8		**RISK TREATMENT**	

3.8.1	RISK TREATMENT	Process to modify **risk**.	NOTE 1 Risk treatment can involve: avoiding the risk by deciding not to start or continue with the activity that gives rise to the risk; taking or increasing risk in order to pursue an opportunity; removing the risk source; changing the likelihood; changing the consequences; sharing the risk with another party or parties (including contracts and risk financing); and retaining the risk by informed decision. NOTE 2 Risk treatments that deal with negative consequences are sometimes referred to as “risk mitigation”, “risk elimination”, “risk prevention” and “risk reduction”. NOTE 3 Risk treatment can create new risks or modify existing risks.
	Risk reduction measure		Set of actions allowing modification of risk. Risk Reduction Measures (RRM) includes any process, policy, device, practice, or other actions which modify risk and may not always exert the intended or assumed modifying effect. (PREPARED project- Almeida *et al.*, 2011b)
	Risk reduction action		Specific action needed to properly implement the selected Risk Reduction Measures (RRM). Actions can be of very different nature. (PREPARED project- Almeida *et al.*, 2011b)
ISO Guide 73:2009, defin. nº	**Terms**	**Definitions**	**CLARIFICATION AND OTHER SOURCES**
3.8.1.1	Control	Measure that is modifying **risk.** NOTE 1 Controls include any process, policy, device, practice, or other	

		actions which modify risk. NOTE 2 Controls may not always exert the intended or assumed modifying effect.	
3.8.1.2	Risk avoidance	Informed decision not to be involved in, or to withdraw from, an activity in order not to be exposed to a particular **risk.** NOTE Risk avoidance can be based on the result of **risk evaluation** and/or legal and regulatory obligations.	
3.8.1.3	Risk sharing	Form of **risk treatment** involving the agreed distribution of **risk** with other parties. NOTE 1 Legal or regulatory requirements can limit, prohibit or mandate risk sharing. NOTE 2 Risk sharing can be carried out through insurance or other forms of contract. NOTE 3 The extent to which risk is distributed can depend on the reliability and clarity of the sharing arrangements. NOTE 4 Risk transfer is a form of risk sharing.	
3.8.1.4	Risk financing	Form of risk treatment involving contingent arrangements for the provision of funds to meet or modify the financial consequences should they occur.	
3.8.1.5	Risk retention	Acceptance of the potential benefit of gain, or burden of loss, from a particular **risk** NOTE 1 Risk retention includes the acceptance of **residual risks.** NOTE 2 The **level of risk** retained can depend on **risk criteria.**	
3.8.1.6	Residual risk	Risk remaining after risk treatment. NOTE 1 Residual risk can contain unidentified risk. NOTE 2 Residual risk can also be known as “retained risk”.	

ISO Guide 73:2009, defin. nº	Terms	Definitions	CLARIFICATION AND OTHER SOURCES
3.8.1.7	Resilience	Adaptive capacity of an organization in a complex and changing environment.	Adaptive capacity of a system to endure any perturbation, like floods, droughts or other hazardous event, maintaining significant levels of efficiency in its social, economic, environmental and physical components. NOTE Resilience to a hazardous event damages can be considered only in places with past events, since the main focus is on the experiences encountered during and after the events
3.8.2.1	Monitoring	Continual checking, supervising, critically observing or determining the status in order to identify change from the performance level required or expected. NOTE Monitoring can be applied to a risk management framework, risk management process, risk or control.	
3.8.2.2	Review	Activity undertaken to determine the suitability, adequacy and effectiveness of the subject matter to achieve established objectives. NOTE Review can be applied to a risk management framework, risk management process, risk or control.	
3.8.2.3	Risk reporting	Form of communication intended to inform particular internal or external **stakeholders** by providing information regarding the current state of **risk** and its management.	
3.8.2.4	Risk register	Record of information about identified **risks.** NOTE The term “risk log” is sometimes used instead of “risk register”.	
3.8.2.5	Risk profile	Description of any set of **risks.** NOTE The set of risks can contain those that relate to the whole organization, part of the organization, or as otherwise defined.	
3.8.2.6	Risk management audit	Systematic, independent and documented process for obtaining evidence and evaluating it objectively in order to determine the extent to which the **risk management framework**, or any selected part of it, is adequate and effective.	

ANNEX II – RISK ASSESSMENT TOOLS AND TECHNIQUES

Adapted from ISO 31010:2009 (ISO, 2009c)

Tools and techniques	Risk Assessment process					See Annex
	Risk Identification	Risk Analysis			Risk evaluation	
		Consequence	Probability	Level of risk		
Brainstorming	**SA**	NA	NA	NA	NA	B 1
Structured or semi-structured interviews	**SA**	NA	NA	NA	NA	B 2
Delphi	**SA**	NA	NA	NA	NA	B 3
Check-lists	**SA**	NA	NA	NA	NA	B 4
Primary hazard analysis	**SA**	NA	NA	NA	NA	B 5
Hazard and operability studies (HAZOP)	**SA**	SA	A	A	A	B 6
Hazard Analysis and Critical Control Points (HACCP)	**SA**	SA	NA	NA	SA	B 7
Environmental risk assessment	**SA**	SA	SA	SA	SA	B 8
Structure « What if? » (SWIFT)	**SA**	SA	SA	SA	SA	B 9
Scenario analysis	**SA**	SA	A	A	A	B 10
Business impact analysis	**A**	SA	A	A	A	B 11
Root cause analysis	**NA**	SA	SA	SA	SA	B 12
Failure mode effect analysis	**SA**	SA	SA	SA	SA	B 13
Fault tree analysis	**A**	NA	SA	A	A	B 14
Event tree analysis	**A**	SA	A	A	NA	B 15
Cause and consequence analysis	**A**	SA	SA	A	A	B 16
Cause-and-effect analysis	**SA**	SA	NA	NA	NA	B 17
Layer protection analysis (LOPA)	**A**	SA	A	A	NA	B 18
Decision tree	**NA**	SA	SA	A	A	B 19
Human reliability analysis	**SA**	SA	SA	SA	A	B 20
Bow tie analysis	**NA**	A	SA	SA	A	B 21
Reliability centred maintenance	**SA**	SA	SA	SA	SA	B 22
Sneak circuit analysis	**A**	NA	NA	NA	NA	B 23
Markov analysis	**A**	SA	NA	NA	NA	B 24
Monte Carlo simulation	**NA**	NA	NA	NA	SA	B 25
Bayesian statistics and Bayes Nets	**NA**	SA	NA	NA	SA	B 26
FN curves	**A**	SA	SA	A	SA	B 27
Risk indices	**A**	SA	SA	A	SA	B 28
Consequence/probability matrix	**SA**	SA	SA	SA	A	B 29
Cost/benefit analysis	**A**	SA	A	A	A	B 30
Multi-criteria decision analysis (MCDA)	**A**	SA	A	SA	A	B 31

SA - Strongly applicable
NA - Not applicable
A - Applicable.