CRANFIELD UNIVERSITY

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STRATEGIC RISK MANAGEMENT IN WATER UTILITIES: DEVELOPMENT OF A HOLISTIC APPROACH LINKING RISKS AND FUTURES

SCHOOL OF APPLIED SCIENCES

PhD
Academic Year: 2013 - 2014

Supervisors: Simon Pollard and Fiona Lickorish

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ABSTRACT

Risk management plays a key role in water utilities. Although tools are well established at operational and tactical levels of management, existing methods at strategic level lack a holistic treatment and a long-term perspective. In fact, risks are analysed *per se*, despite being interconnected; and long-term scenarios are commonly used for strategic planning, rather than for risk management, most of the time being related to one single issue (for example: climate change).

In order to overcome the limitations identified in the existing methodologies, a novel approach for water utilities to manage risk at strategic level was developed and tested in EPAL - the largest and oldest water utility in Portugal. It consists of (i) setting a baseline risks comparison founded on a systemic model developed 'bottom-up' through the business; (ii) the construction of future scenarios and an observation of how baseline risks may change with time.

Major contributions of this research are the linkage between operational and strategic risks, capturing the interdependencies between strategic risks; the ability to look at long term risk, allowing the visualizing of the way strategic risks may change under a possible future scenario; and the novel coupling of risks and futures research.

For the water sector, this approach constitutes a useful tool for strategic planning, which may be presented to the Board of Directors in a simple and intuitive way, despite the solid foundations of the underlying analysis. It also builds on in-house expertise, promoting the dissemination and pervasiveness of risk management within the companies and, on the other hand, allowing unveiling of existing knowledge, making it explicit and more useful for the organization.

Keywords:

Strategic risk management, futures, scenario building, water utilities, risk analysis, corporate management

ACKNOWLEDGEMENTS

My first thoughts go to my supervisors: Simon Pollard, who was exceedingly attentive, opportune and masterful; and Fiona Lickorish, who enlightened me about the futures' science, in such a thoughtful and proficient way. I am also grateful to Savina Velotta, for being so helpful and efficient with the logistics.

I owe my deepest gratitude to the members of the Board of EPAL who made this project possible, not only by challenging me to undertake it, but also by making all the necessary conditions available: João Fidalgo, António Bento Franco, (late) Jorge Loureiro, José Sardinha, Maria do Rosário Águas and Maria do Rosário Ventura. My sincere thanks to the corps of risk managers and risk experts of EPAL, whose contribution to test the proposed methodology was crucial, as well as to Luis Marçal, for helping with the design of the figures, and to Patrícia Duarte, for transcribing the notes from the interviews into the Excel database.

I thank Prof. Tom Ritchey from the Swedish Morphological Society, for making Carma™ available and for his prompt comments and instructions.

My warmest "Thank you" to all my friends that gave me their support during this long run – it was a real comfort.

A special greeting to my mother, who backed me up from the beginning and who so many times took care of little Clara on my behalf. I received my father's blessings from where he is, together with God – his presence was surely stronger than his physical absence. I also thank my sister and brother, for their full support throughout my academic and professional careers.

My last words are for my dear husband, Fernando, and for my three kids, António, Marta and Clara. Thank you so much, Fernando, for taking up this project as "ours", and for having done everything you could towards its success; thank you António and Marta, for being such nice and mature kids – I hope this project may be inspirational for your future careers; and thank you Clara, for sharing the first three years of your life with this PhD, in such a cheerful and enchanting way.

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LIST OF ABBREVIATIONS

AS/NZS	Australian/New Zealand Standard
BSI	British Standards Institute
CAPEX	Capital Expenditure
CCA	Cross-Consistency Analysis
CERF	Centre for Environmental Risks and Futures
CIA	Cross Impact Analysis
CIESIN	Center for International Earth Science Information Network
COSO	Committee of Sponsoring Organizations of the Treadway Commission
DEFRA	Department for Environment, Food and Rural Affairs
EEA	European Environment Agency
EPAL	Empresa Portuguesa das Águas Livres, SA
ERM	Enterprise Risk Management
FAO	Food and Agriculture Organization
FMEA	Failure Modes and Effects Analysis
FMECA	Failure Modes, Effects and Criticality Analysis
HR	Human Resources
IPCC	Intergovernmental Panel for Climate Change
ISO	International Organisation for Standardisation
MA	Morphological Analysis
NJDEP	New Jersey Comparative Risk Project
OPEX	Operational Expenditure
PAS	Publicly available standard
PMT	Probabilistic Modified Trends
SRA	Strategic Risk Analysis
SRES	Special Report on Emissions Scenarios
TIA	Trend Impact Analysis
USEPA	United States Environmental Protection Agency
US-NRC	United States National Research Council
WHO	World Health Organization
WSP	Water Safety Plan
WTP	Water Treatment Plant

1 INTRODUCTION

1.1 Context and background

Risk management plays a key role in water utilities. Water is a critical resource for human survival and cannot be taken for granted by water-dependent businesses, as across the entire product value chain there are internal and external factors, some of which are uncontrollable, that threaten the overarching aim of water utilities (Morrison and Gleick, 2004) – to deliver safe, wholesome and affordable drinking water that has the trust of customers (Pollard *et al*., 2004).

Risk is generally understood as the uncertainty associated with events that pose a threat to the business (ISO 31000, 2009; Hrudey, 2005; Almeida, 2011). In purely mathematical terms, this is expressed by probability times consequence(s), so defining a time frame for the analysis as well as outlining what consequences are associated – “risk of what to whom” (Pollard, 2008) – becomes an imperative when undertaking any risk analysis. This means that the evaluation of risk in the water sector, which deals with both technical and social risks (Renn, 2008a), is not a straightforward task: on the one hand, technical (factual) risks may be assessed statistically, but the correspondent numerical value is too reductionist to properly describe the complex interactions between human activities and consequences (Renn, 2008a); on the other hand, socially constructed risks are subjective and based on human perception, rather than on statistical evidence (Slovic, 1987; Slovic, 1998). A need to move towards an integrated understanding of risks has been noted in recent years (Hamilton *et al.*, 2006; Renn, 2008b; Larson *et al.*, 2009; Prpich *et al*., 2011).

Water supply management is, in fact, subject to a mix of technical and social risks. It depends on diverse drivers such as political, economic, social, technological, regulatory and, of course, environmental. Spatially, it comprises not only the infrastructural system, but also the supplied region as well as the entire river basins and/or aquifers where the intakes are located. In terms of time horizons, assets are designed to last 25 to 50 years, though the demand may change in shorter periods of time and the water supply system as a whole is expected to last for generations. Legislation and regulation contribute to shape water utilities' operational procedures, aiming to protect the consumers, but tension arises if it implies an increase in operational costs that utilities cannot directly reflect in tariffs, due to economic regulation, thus creating a threat to business profitability and sustainability (Pollard *et al.*, 2004). All of this makes water supply strategic planning fall into the category of "wicked problems": complex, long-term social and organisational planning problems (Ritchey, 2013).

The inexistence of formal procedures for risk assessments until the 90s made risk management depend on individual perceptions and decisions, which are subject to amplification (Renn, 2008b). By "amplification", Renn means both exaggeration and depletion of risks, which contribute to either an over protection against risks, or to a "blind" operation of the business (Carter, 2012), respectively. Due to the huge responsibility concerning public health safety, and because the human mind reacts to bad things "more quickly, strongly, and persistently than to equivalent good things" (Haidt, 2006), in water utilities risks used to be consciously or unconsciously exaggerated - rather than reduced - by managers, so that more power was granted to them (Slovic, 1998; MacGillivray and Pollard, 2008). This may partially explain why risks have historically been managed in silos, instead of seeking a common understanding, and points out the relevance of having open, transparent and integrated processes for risk evaluation, ultimately contributing to increasing the overall business efficiency.

In terms of risk management, the water sector is behind other sectors like oil, gas and electricity (Egerton, 1996 in Pollard *et al.*, 2004). Moreover, in the water sector risk managers are usually conservative and tend to focus on maintaining the *status quo* of established norms (Larson *et al.*, 2009). Notwithstanding, these paradigms are changing. Since 2001, a major shift has occurred in the way water utilities manage their organizations, by adopting basic risk management processes (HM Treasury, 2004): in 2004, the Bonn Chart introduced the risk-based concept of Water Safety Planning, WSP (Pollard, 2008); and asset management has been the focus of several national and international risk-based frameworks and standards (e.g.: BSI PAS 55:2004, substantially revised in 2008). No doubt risk awareness has been increasing, and risk management has come to the forefront of the agenda in water utilities. Hence, the main challenge water utilities are facing now no longer lies in the initial identification and analysis of risks, but rather in the on-going review and improvement of risk management practices (HM Treasury, 2004).

Tools for strategic risk management, i.e., the risks of not meeting high-level business objectives (HM Treasury, 2004), are still poorly developed: existing methodologies either adopt risk rankings, where risks are frequently described by an opaque number, or seek full risk characterisation and understanding, from where priorities are difficult to distil (Prpich *et al.*, 2011). These methods invariably assess strategic risks independently - despite risks being interdependent (Hamilton *et al.*, 2006; Pollard *et al.*, 2009) - and the respective outcomes tend to represent a “snap-shot” in time, regardless the fact that strategic objectives are set for the long-term.

On the other hand, future scenarios have been used to inform strategic planning in water utilities, but most of the time focusing on a single specific issue - e.g.: climate change (Means *et al.*, 2010) - and, not rarely, based on extrapolation of past trends (Cosgrove, 2013). These approaches lack the integrated perspective underlying the complexity of the water business and concentrate on projected consequences, thus missing the link with risk management in the future, due to the unaccounted perspective of the projected likelihood.

Overcoming these difficulties represents a challenge, which this research work seeks to answer, through the development of a novel holistic approach linking strategic risks and futures research.

1.2 Motivation

Water utilities are capital intensive, which means that their economic sustainability strongly depends on achieving the correct balance between risk, cost and performance throughout the lifecycle of the respective assets (BSI PAS 55:2008).

As Head of Asset Planning at EPAL – Empresa Portuguesa das Águas Livres, SA, the centenary water company that supplies almost one third of the Portuguese population, the researcher was involved in the implementation of risk based approaches in the company at operational and tactical levels, namely the Water Safety Plan and the delivery of the Capital Investment Plan, respectively. However, no existing methods were found adequate to implement risk management at strategic level, in order to support long-term planning, which led the Board of EPAL to propose the development of a PhD under this theme, funded by the company. This work represents, therefore, a paradigmatic case of practitioner-based research.

And so, at the outset of this work there is a real need from EPAL to better manage risk at a strategic level and, on the other hand, the recognition that existing strategic risk management approaches for water utilities are not yet well developed. The outcomes of this research are expected to expand the scientific knowledge on strategic risk management while providing water utilities - namely EPAL – with a tool to enable them to better achieve their strategic objectives.

1.3 Thesis structure

In chapter two the current literature on strategic risk management and future scenarios is reviewed, with emphasis on the water sector. A gap analysis resulting from the state of the art review is then presented, thus justifying the research objectives identified in chapter three.

Chapter four describes the theoretical approaches used in this research: an action-centred approach employing diverse methods such as (i) observation, conversation, interviews and document analysis to generate qualitative data; (ii) cognitive mapping; (iii) semi-quantitative risk assessments; (iv) development of visualization tools; and (v) morphological analysis to build future scenarios.

Chapter five sets the scene of the case study, namely by introducing a brief description of EPAL, including its water supply system and the respective governance, as well as the roles and responsibilities of the assembled team. The development, implementation and testing of the novel methodology for strategic risk management in water utilities is presented in chapter six, focusing on the three main steps: risk identification; systemic analysis of strategic risks; and futures and long-term strategic risks.

Chapter seven presents a discussion of the research findings, highlighting the novelty and significance of the work in both academic and practical contexts.

Chapters eight and nine offer the conclusions and suggestions for further research, respectively.

1.4 List of Publications, Presentations and Awards

PUBLICATIONS

- Luis, A., Pollard, S. and Lickorish, F. (2014), "Evolution of strategic risks under future scenarios for improved utility master plans", *in preparation to submit to Water Research*
- Luis, A., Lickorish, F. and Pollard, S. (2014), "Assessing interdependent operational, tactical and strategic risks for improved utility master plans", *in preparation to submit to Water Research*
- Allan, R., Mauelshagen, C., Luís, A. M., Jeffrey, P. and Pollard, S. (2013) Making risk management stick: reflections on risk governance in water utilities. In U. Borchers, J. Gray and K. C. Thompson (eds.), *Water Contamination Emergencies: Managing the threats*, RSC Publishing, Royal Society of Chemistry, Cambridge, ISBN 978-1-84973-441-7, pp.33-46, DOI: 10.1039/9781849737890-00033.

CONFERENCE PROCEEDINGS and WORKSHOP PRESENTATIONS

- Luis, A., Lickorish, F., Pollard, S., *Uma nova abordagem para a gestão do risco a nível estratégico para entidades gestoras de abastecimento de água – o case study da EPAL*, 12.º Congresso da Água / 16.º ENaSB / XVI SILUBESA, Lisboa, Portugal, Mar. 2014

- Luis, A., Lickorish, F., Pollard, S., *Managing future risk – a novel approach for strategic risk management in water utilities*, ENEG2013,Coimbra, Portugal, Dec. 2013
- Allan, R., Mauelshagen, C., Luis, A., Jeffrey, P., Pollard, S., *Risk governance and the board: Supporting pervasive risk management in water utilities*, in the Proceedings of the 5th Water Contamination Emergencies: managing the threats, Mülheim-an-der-Ruhr, Germany, Nov. 2012
- Luis, A., Pollard, S., Wu, S., *Strategic Risk Management - Case Study: EPAL*, in the Risk Governance – a water utility manager's implementation guide Workshop, London, United Kingdom, March 2012
- Pollard, S., Luís, A., Mauelshagen, C., *Keynote speech* in the Risk Governance – a water utility manager's implementation guide Workshop, London, United Kingdom, March 2012
- Luis, A., Pollard, S., Wu, S., *Strategic Risk Management for International Water Utilities - State-of-the-art Review*, in the Proceedings of the 11th Water Congress, Porto, Portugal, Feb. 2012

AWARDS

- Honour Awards for the *Planning* Category of the 2014 IWA Europe & West Asia Regional Project Innovation Awards for the project "Managing future risk - a novel approach for strategic planning in water utilities", by EPAL, SA / Cranfield University, Portugal

2 LITERATURE REVIEW

2.1 General considerations

The following chapter begins with the examination of different aspects of risk management, related to this research project. It begins with a broad overview of risk management in the water sector, including established frameworks, tools and techniques, followed by an outline of risk governance issues and a specific attention on enterprise risk management (ERM), or other similar approaches that intend to assess different risks at corporate, strategic level. As strategic risks are long-term changing risks, the literature review proceeds with investigating how future scenarios are set up, how these are being used to inform water utilities in their long-term planning and how they are related to risk management. The main insights from the literature review are summarized at the end of the chapter.

2.2 Risk management in water utilities

2.2.1 Risk management frameworks, tools and techniques

Tools and techniques for the analysis of the different types of risk vary by their sophistication and design, and a wide range of approaches are available (Pollard *et al*., 2004), from the use of standards to the entrenching of safety and risk in the company values.

The most common risk management frameworks (e.g. AS/NZS 4360:2004; ISO 31000, 2009) are embedded in risk assessments approaches or procedures (MacGillivray and Pollard, 2008) with specific purposes in water utilities, such as the water safety plans, which are primarily aimed at securing drinking water quality (Pollard, 2008); asset management practices, that envisage the optimization of maintenance and rehabilitation decisions in order to maximize assets' useful life (BSI PAS 55:2008); or occupational health and safety procedures (Molak, 1997).

Methodologically, at the outset of any risk assessment exercise, the clear and explicit <u>problem formulation</u> – risk of what, to whom – is critical (Pollard, 2008).

Then, all frameworks evidence a double step approach[1]: first, the evaluation of risk; secondly, the analysis of the risk, based on risk tolerability criteria, followed by the proposal of risk treatment measures (Figure 2-1):

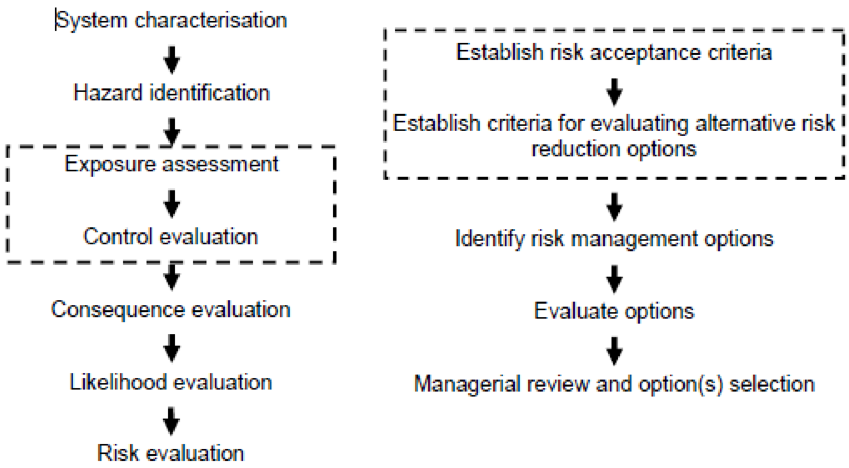

Figure 2-1 - Risk evaluation (left) and risk based decision making practices (right) (MacGillivray and Pollard, 2008)

- Risk evaluation

after the problem formulation phase is ready, hazards identification can be undertaken, usually by relevant experts on the risks being analysed, who also identify the existing exposures and controls. Risk identification requires consistent choices regarding how hazards are grouped – they may be categorized in terms of the stressor agent (e.g.: lead), the activity causing the hazard (e.g.: mining), the endpoint of concern (e.g.: people) and so on (Willis *et al.*, 2004).

Consequence and likelihood may be evaluated using quantitative, qualitative or semi-quantitative methods. Usually, the more focused the analysis is, the more that quantitative methods can be applied (Gormley *et al.*, 2011; Ray *et al.*, 2008; Pollino *et al.*, 2007). For example, water utilities typically adopt this type of methods for assessing the risk of assets'

[1] A comprehensive portfolio of methods that may be used in the risk evaluation step is presented in ISO 31000 (2009).

mechanical failures. Nevertheless, recent research evidences these methods are expanding to assess risks at system level (Lindhe *et al.*, 2009; Lindhe *et al.*, 2012). Quantitative methods are less subject to ambiguity (Gormley *et al.*, 2011) and allow the determining of absolute risk measured on whatever scale of units is chosen (Altenbach, 1995). However, they require historical data in order to determine probability distributions, as well as trained people; they may be too time consuming or costly (Altenbach, 1995) and, in case more than one dimension is analysed, a common measure for consequences shall be defined (Llewellyn, 1998; Almeida, 2011).

Semi-quantitative risk assessments offer a lot of advantages, as they may be used even if there is insufficient data for detailed analysis and are more transparent, since no sophisticated mathematical model is necessary (FAO/WHO, 2009). They are also able to evaluate a larger number of risk issues, offering a consistent and systematic approach when risk prioritization is required (Gormley *et al.*, 2011), and can either incorporate the results of fully quantitative risk assessments (FAO/WHO, 2009) or be used as initial screening for subsequent quantitative analysis (AS/NZS 4360:2004). Semi-quantitative risk assessments often require the same data as a qualitative risk assessment, but have a greater focus on attempting to evaluate the components of the risk to within defined quantitative bounds (FAO/WHO, 2009). These methods are widely adopted by water utilities, usually by placing the risks into quite broad sets of categories, for example five for probability and five for impact, not including zero, which gives 25 possible combinations (FAO/WHO, 2009; Pollard *et al.*, 2013). Therefore, care must be taken so that categories are wisely constructed, because the numbers chosen may not properly reflect relativities and, even so, numbers should only be combined using a formula that recognizes the limitations of the kinds of scales used (AS/NZS 4360:2004); otherwise, semi-quantitative methods can lead to inconsistent, anomalous or inappropriate outcomes, particularly when either consequences or likelihood are extreme (AS/NZS 4360:2004; Cox, 2008).

Cox (2008) examines some of the mathematical properties of risk matrices and concludes that they frequently exhibit the following limitations: (a) poor resolution – two quantitatively very different risks may have been rated equally; (b) errors – depending on the way they are built, higher qualitative ratings can be assigned to smaller risks; (c) suboptimal resource allocation; (d) ambiguous inputs and outputs, as they require subjective interpretation. He then introduces the concept of *weak consistency* to explain logical compatibility of risk matrices with quantitative risks, from where some *lemmas* or rules for building risk matrices are derived.

When using semi-quantitative methods, consequences are described by attributes, and choosing a set of attributes that comprehensively describe hazards' impacts while keeping the list short enough to be cognitively tractable, remains a challenge – it requires methodological compromise to balance totality and usability (Willis *et al*., 2004; Prpich *et al*., 2011).

Though the order through which likelihood and consequences are assessed is considered to be interchangeable by most risk frameworks – or, at least, no reference is made about it –, MacGillivray and Pollard (2008) reasoned that ranking impacts should be done first, because evaluating likelihood detached from a specific consequence leads to an overestimation of risk. Moreover, assessing likelihood first has the potential for major risks to be dismissed prematurely (Caldwell, 2012).

- Risk based decision making

How organizations develop an understanding of their <u>appetite for risk</u> is poorly understood and few formal approaches appear to be in place (HM Treasury, 2004; Pollard *et al*., 2005; Allan *et al.*, 2013). At the stage of a specific risk, though, an acceptable level of exposure can be defined in terms of both a "tolerable impact" and a "tolerable frequency", against which residual risk – i.e., the risk left over after a risk treatment option has been implemented, removing the source of the risk, modifying the consequences, changing the probabilities, transferring the risk, or retaining the risk (ISO 31000, 2009) – may be compared to decide whether or not further action is required (HM Treasury, 2004). It is worth noting that “zero risk” does not exist, and there is no sharp line between safe and unsafe, because safety has a meaning on a relative basis (Hrudey, 2005). A new concept related to *risk appetite* is now arising: the *risk attitude* (ISO 31000, 2009). The main difference between the two of them is that *risk appetite* depends on the organizational culture, driven by individuals’ values and their propensity for risk taking (Pollard *et al.*, 2013), whereas *risk attitude* evidences the level of risk a company is actually approaching, by considering the control barriers in place or the need to revise them. Risk attitude is, therefore, more focused on the residual risk.

Translating concerns about risks to risk management priorities is not a straightforward task (Willis *et al.*, 2010). Making credible and defendable decisions in organizations requires an institutional capacity to be predictive rather than reactive when managing risk, and an aptitude to learn from experience (Pollard *et al.*, 2004; MacGillivray and Pollard, 2008; Hrudey, 2005). MacGillivray and Pollard (2008) state that the outputs of a risk analysis should provide decision support, not “carte blanche” decisions. The same idea is emphasized by Hrudey (2005): for most of the difficult risk management issues concerning drinking water, the level of uncertainty about the nature and magnitude of risks will be too large for the risk estimates alone to determine the best course of action for risk management; therefore, good risk management must inform but will not dictate most risk management decisions. Similarly in other areas of difficult decision-making, like individual medical care, Hrudey (2005) advocates that it is appropriate for risk managers within the water industry to consider the merits of a set of ethical principles to guide risk management actions to: i) do more good than harm; ii) fair process of decision-making; iii) ensure an equitable distribution of risk; iv) seek optimal use of limited risk management resources; v) promise no more risk management than can be delivered; vi) impose no more risks than you would tolerate yourself.

At the end of any risk assessment, legitimate concerns about its credibility and validity often arise. Expertize, impartiality, adherence to good scientific practice and transparency, are some commonly identified attributes to assure the credibility of risk assessments (Wiedemann *et al.*, 2013; FAO/WHO, 2009; ISO 31000, 2009; Hokstad and Steiro, 2006). Despite their credibility, which derives mainly from competence and trustworthiness (Hovland, 1959 and Hovland and Weiss, 1951 in Wiedemann *et al.*, 2013), risk assessments still need to be validated. The outcomes of the risk evaluation phase should be validated by risk experts, either when the results meet the initial expectations, or, and especially, when odd things show up.

As noted by Rosness (1998) in MacGillivray and Pollard (2008), the accuracy of risk analyses depends to a large extent on the competency of analysts to critically evaluate information and integrate it, so education and training in risk analysis (Summerill *et al.*, 2010), irrespective of the technical complexity of the methods adopted, is a must. To avoid human error or bias, risk identification and the correspondent evaluation of likelihood and consequences, as well as the validation of the results, may be done through peer reviews or expert elicitation, the latter requiring adequate facilitation (Johnson and Johnson, 2000) so that no opinion leader prevents others from being heard and, on the other hand, a consensus may be reached even if initial disagreements occur (Willis *et al.*, 2004; Vlek, 2013; MacGillivray and Pollard, 2008; Powers *et al.*, 2012).

2.2.2 Risk governance

It has been recognized that risk analysis needs to go beyond the boundaries of engineered systems to also include management and human factors (Pollard *et al.*, 2005; Schiller and Prpich, 2013). Risk research has recently turned to understanding organisations and their capability to manage risk (Power, 1999, 2008 and Hutter and Power, 2005 in Schiller and Prpich, 2013; Summerill *et al.*, 2010; Allan *et al.*, 2013).

Generally, three levels of risk management involving different actors within an organization can be pointed out: *operational* – operational staff; *tactical* – middle managers; and *strategic* – the Board and corps of directors or senior managers (Pollard *et al*., 2013). Operational teams manage risks on an everyday basis, even if they might not be aware of that (Allan *et al.*, 2013), by ensuring the effectiveness of existing controls (e.g.: sensors, membranes, chlorination points, etc.). Middle management within utilities plays a key role in ensuring that risks are managed appropriately within the organisation, and their focus tends to be risks posed by a similar hazard at diverse locations (Pollard *et al*., 2013), time bounded to the financial year (Allan *et al.*, 2013). Board members, directors and senior managers may take a longer term strategic view of the company, and are usually most interested in the financial stability and wellbeing of the organisation they lead, through the accomplishment of the strategic objectives (Allan *et al.*, 2013). Through their buy-in and leadership, the board and senior management are critical for the implementation and internalizing of corporate risk management across business functions (Fraser and Simpkins, 2009 in Pollard *et al*., 2013; Summerill *et al.*, 2010), as well as for securing open communication with external stakeholders, thereby shaping the organizational culture (Pollard *et al.*, 2009).

The need to improve communication between experts, managers and the Board has been noted (Summerill *et al.*, 2010; Allan *et al.*, 2013), whether risk governance is centralized in a dedicated team (which often includes auditing functions) or spread among employees with other core responsibilities (Pollard *et al.*, 2013). Both models present advantages and disadvantages, but guaranteeing that information flows across the different levels in the organization is what makes risk management truly effective (MacGillivray *et al.*, 2006; Hrudey *et al.*, 2006). Best in class utilities have developed proper tools (e.g. web-based technology) in order to facilitate information sharing (Pollard *et al.*, 2013).

As a whole, organizations may face different stages of maturity in risk management. MacGillivray and Pollard (2008) define the highest level of maturity as the state where an organization is capable of learning and adapting itself – a challenge that the majority of water utilities have not met, yet, as we can infer from Summerill *et al.* (2010) and Allan *et al.* (2013). Previous stages include processes that are ad-hoc (level 1), repeatable (level 2), defined (level 3) and controlled (level 4). Benchmarking their own capability maturity level is important for water utilities, because institutional capacities, rather than technical aspects, are the fundamental limiting factor in implementing and securing the pervasiveness of risk management (MacGillivray and Pollard, 2008; Allan *et al.*, 2013). Establishing key performance indicators for risk management may help internal auditing (Pickett, 2005 and UK government's Risk Support Team, 2004 in Pollard *et al.*, 2013), although risk management is often described by directors as an audit and bureaucratic function rather than as a process improvement used to leverage off competitive advantage (Allan *et al.*, 2013).

2.2.3 Strategic risk assessments

Concepts like "corporate risk management", "enterprise risk management", "strategic risk management" and so forth, are based on the principle that risk management is an overarching strategic discipline, rather than a regionalized process within individual business functions (MacGillivray and Pollard, 2008). For water utilities, corporate risk management involves the comparison of a large number of diverse environmental, engineering and security risks (Prpich *et al*., 2011), as well as project, commercial and financial risks, such as those associated with infrastructure investment, merger and acquisition activities, company reputation, outsourcing and the long term viability of investment decisions (Pollard *et al*., 2004; Pollard *et al*., 2005). Moreover, besides providing information for water utilities to direct resources, plan research efforts and devise strategies to address the worst risks, corporate risk management is also expected to improve the culture of risk and communication across business functions within utilities, and, most of all, to contribute for knowledge generation (Schiller and Prpich, 2013).

In water utilities, most risk management processes have been developed at operational and tactical levels, like the ones used to support occupational health and safety procedures, water safety plans and mid-term asset management plans. The need to move to a strategic level is obvious, if strategic risks are thought of as “high-level risks that threaten corporate objectives”, including “the utility’s licence to operate” and “the ability to secure lasting revenue to support strategic investment plans”, among others (Pollard *et al.*, 2013). Four main reasons can be pointed out for the limited implementation of strategic risk assessments: (i) the challenge of dealing with a higher number of risk dimensions, requiring multi-disciplinary knowledge (Almeida, 2011); (ii) the difficulty of capturing risks interconnections; (iii) the need to establish cross-departmental communication, which may represent a big effort at large utilities (Prpich *et al.*, 2011); and (iv) the higher degrees of uncertainty involved, due to spatial and temporal variability. In fact, strategic objectives are, in their nature, long-term objectives (Keeney, 1992), so the risk of not meeting those objectives should also be assessed in the mid and long-term, as they can be affected by changing trends in population growth, asset deterioration, climate change, land use, technological developments and other known or unknown elements (Pollard *et al.*, 2013).

Conventionally, present-day strategic risks as well as risks prone to upsurge in the long-term, have been, despite their interconnections, appraised in isolation but there is a growing recognition of the need to integrate and harmonize these analyses (Means *et al*., 2010; Hamilton *et al.*, 2006; Renn, 2008b; Larson *et al.*, 2009; ISO 31000, 2009; Prpich *et al*., 2011).

Attempts to relate physical or environmental risks like water quality, supply and resource have existed for over a decade (Bouwer, 2000; Hamilton *et al.*, 2006; Pollard *et al.*, 2004; Powers *et al.*, 2012). The first generation of environmental strategic risk analysis (SRA) tools sought to establish nominal rankings, and an extensive work on this domain was developed by the US Environmental Protection Agency, USEPA (Prpich *et al.*, 2011). Most of these tools used a common measure to characterize harms, so that comparisons could be made (Almeida, 2011; Llewellyn, 1998). Nonetheless, this way of comparing and ranking risks of a different nature was generally criticized due to the multi-dimensional nature of environmental harms, which makes any quantitative ranking exercise necessarily imperfect, giving way to the second generation of SRA. These tools then emphasized the importance of a good and comprehensive characterization of the risks and the respective tolerability, rather than the setting of quantitative ranks – the broad framework for risk assessment and risk management for environmental protection set out by the Environment Agency of England and Wales is a good example (Prpich *et al.*, 2011; Llewellyn, 1998). However, implementation difficulties related to communication issues (e.g. tensions between scientists and decision makers; tensions between the objectives stated by the Boards and what the technical staff believed to be important) revealed that this new approach had still to be improved (Prpich *et al.*, 2011). Therefore, a third generation of SRA tools is now emerging, focusing on a more realistic approach about what can be achieved, and on the delivery of a set of visualizations that can provide a base for rich discussions and understanding of the risks, instead of delivering a "top-ten" ranking (Prpich *et al.*, 2011). One of the main challenges consists of detailing the analysis as much as possible, in order to make it defendable, while keeping it simple enough for decision-makers to understand it (Prpich *et al.*, 2011). The work developed for Defra – the UK Government Department for Food and Rural Affairs, with the purpose of comparing environmental strategic risks (Prpich *et al.*, 2011) constitutes a good example of these third generation tools.

In spite of these attempts to integrate physical/environmental risks, a step change is still required to, like other sectors (e.g: electricity), further integrate water risks with business, financial and other corporate risks, given the ever more complex and interconnected risk environment driven by increased globalisation, supply chain, innovation, outsourcing and strategic alliances (Frigo and Anderson, 2012).

In response to this problem, the concept of enterprise risk management has grown in the last decade to become the dominant business risk paradigm (COSO, 2004). ERM was initially developed in the finance and insurance sectors to manage risks associated with investments and liability, but now it stands separate from other organisational risk management systems as the only one that attempts to integrate strategic, financial, hazard and operational risk into a single framework to inform an organisation's strategic objectives (Hoffman, 2008; Schiller and Prpich, 2013) - it is even open to including cultural organizational risks (Schiller and Prpich, 2013). One of the most well-known ERM frameworks is the COSO framework, which was developed by the private Committee of Sponsoring Organisations of the Treadway Commission in 1992, and revised in 2004.

The concept of ERM has expanded to regional or national levels, as well (e.g. HM Treasury, 2004). Several national risk assessments have been undertaken internationally, with the Netherlands and the UK in leading positions since 2007 (Vlek, 2013), and these are now spread across not only Europe but also Australia, Canada, New Zealand and the United States (Vlek, 2013).

Most literature on ERM is produced by consultants, whereas business case reports are often confidential, and there is little scientific investigation on this subject (Schiller and Prpich, 2013). Nonetheless, the following fundamental conceptual weaknesses of ERM may be evidenced:

- Current methods to aggregate risk within ERM are semi-quantitative, using ordinal assessments of risk in a risk matrix, which, as mentioned above, do not provide an objective, quantitative means to integrate multiple risks or prioritise risk mitigation options – they can, instead, be used as a basis to enrich discussions about the risks.
- While integrating different risks creates the opportunity to optimise business plans and strategies for risk and reward, it also creates a risk of inappropriate risk to risk trade-offs (Schiller and Prpich, 2013). For example, business risks may be inappropriately compared to water quality and public health risks (where risk appetite is lower), so risk appetite and tolerance should clearly be stated separately for each type of risk (Rittenberg and Martens, 2012).
- ERM ignores the possibility of incommensurability and incomparability among risks, as its framework is strongly commensurable (COSO 2004;

HM Treasury 2004) – this may explain why ERM implementation has come to add ever more risks to the portfolio (Schiller and Prpich, 2013).

- No existing ERM framework has consideration for the differences between organisations and their diverse institutional contexts (Shiller and Prpich, 2013). This is particularly relevant for water utilities, because the effects of water are felt locally and depend on external contexts that differ from basin to basin.
- ERM guidance (e.g. COSO 2004; HM Treasury 2004) suggests that organisations can only address risks to the strategy or objective of organisations, inhibiting the search for 'known unknowns' or 'unknown unknowns' (Schiller and Prpich, 2013). This is seconded by the way in which some risk assessments are conducted, namely when communication with risk experts is made through emailed inquiries, rather than through appropriate forums of discussion, that would enable the sharing of information among different experts, minimizing bias, as well as the opportunity for new risks to come up.
- ERM does not take into account that most risks are interdependent as they are embedded in complex social systems, nor acknowledges that interdependencies between risks are also created by the ERM process itself, not least through the competing budget (Beasley and Frigo, 2007 in Schiller and Prpich, 2013).
- Consentaneously with SRA, ERM should consider the long-term evolving risks, though there is no empirical evidence that this has been done already.

As a result of the above, water utility risk management, in its integrated form, might be viewed as entering a new era whereby risk specialists have far closer engagement with financial modellers, economists, business planners and information technology specialists, in addition to their existing engagement with water treatment and distribution engineers on issues such as safety, public health and water quality (Schiller and Prpich, 2013). However, until now the technologies and advocacy required to fully achieve integrated enterprise risk management have not emerged, and the arbitrary, biased and limited implementation of the existing frameworks may create a false belief that corporate risks are being properly managed (Schiller and Prpich, 2013).

2.3 Future scenarios

2.3.1 Evolution of futures studies

Scenarios are plausible descriptions of how the future may develop, based on a coherent set of assumptions about key relationships and driving forces - they are neither predictions nor forecasts, but plausible future chains of cause and effect (CERF, 2012; Kahn, 1967 in Amer *et al.*, 2013).

Historically, Kuosa (2011) suggests that there are three paradigms in the evolution of future scenarios. The first one is the “age-old prediction tradition that combines thinking about the future with mystic explanations”, like prophecies. The second paradigm is the emerging of futures research as a discipline, still considered radical by many (Defra, 2008), which was initiated by the US Military after the second world war (Kuosa, 2011; Amer *et al.*, 2013; Van der Heijden, 1996 in Varum and Melo, 2010). According to Kuosa (2011), there are three phases in this second paradigm: (i) the 40s and 50s – a post war golden time of planning, trade, space travel and other technological foresights in general, when the main actors in futures research were think tanks and research units of the US military, like Herman Kahn from RAND, Research ANd Development (Amer *et al.*, 2013); Snowden (2010, in Kuosa, 2011) described this phase as *Management oriented*, with the aim of controlling functions; (ii) the 60s-70s, when the increasing awareness of long-term effects of social movements, population and economic growth leveraged futurists to emerge beyond the military centres, like the paradigmatic case of Pierre Wack from Royal Dutch Shell – the first documented experience evidencing how better-prepared Shell was coping with the oil crisis in the 70s (Wack, 1985 in O’Brien, 2004); this was also the period when the majority of the existing tools and techniques were developed; (iii) from the 80s till now, when a stabilization of the discipline occurred, along with an overall fragmentation and a search for this field identity – this and the former phases were designated by Snowden (2010, in Kuosa, 2011) as *Systems thinking oriented*, aiming at controlling information.

Kuosa (2011) advocates that a third paradigm in futures research is now emerging, where “studies are moving towards critical hermeneutical understanding, emancipatory dialects, and diversity”; this will be *Systems and Cognition oriented*, aiming to “identify structures of network, optional connections, constraints and contexts” (Snowden, 2010 in Kuosa, 2011), enabling a “new understanding of dynamical systems” and developing “applicable interdisciplinary methodology”. Kuosa (2011) warns that though *Systems thinking* is coming to an end, it does not necessarily mean that the third paradigm is immediately reached, since it requires “hard work and willingness to a new mindset”. Figure 2-2 illustrates the evolution of futures research, according to Kuosa (2011).

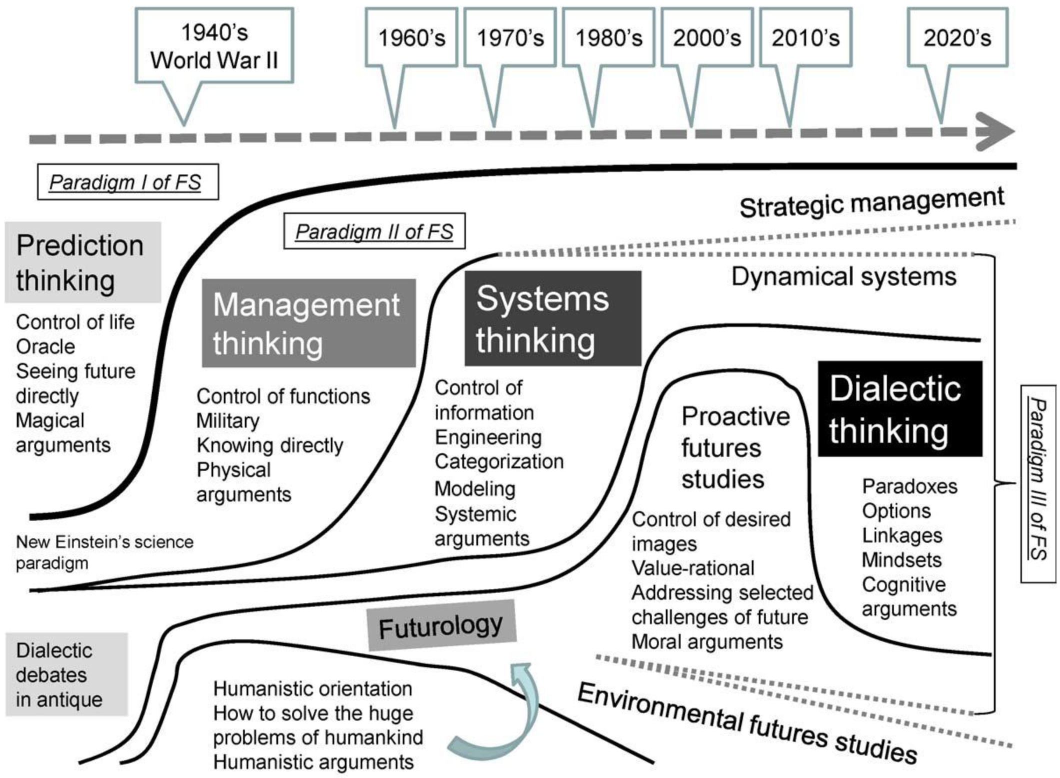

Figure 2-2 – Evolution of futures studies (Kuosa, 2011)

Future scenarios have been widely used as a strategic management tool, in order to support companies, agencies, governments, etc. devising long-term strategies (O’Brien, 2004; Chermack *et al.*, 2001 and Porter *et al.*, 1991 and Saritas *et al.*, 2004 in Amer *et al.*, 2013) – as a collateral benefit, many state that the opportunity to open “mental maps” of managers and to initiate new conversations – the process – is as important, if not more so, than the strategies themselves – the product (Wack, 1985 in Brummell and MacGillivray, 2008; Amer *et al.*, 2013). In a world with ever more complex interactions between the economic, environmental, technological, or socio-political sectors of society, scenarios help in dealing with the unpredictability of future events (Malaska *et al.,* 1984 in Amer *et al.*, 2013; O'Brian, 2002; Habegger, 2010; Saritas and Nugroho, 2012), and are suitable to address what Rittel and Webber (1973 in Ritchey, 2013) designated as *wicked problems*: complex, long-term social and organisational planning problems. Nonetheless, apart from capital intensive industries like aerospace, petroleum, etc. (Amer *et al.*, 2013), Lemmens and Munsters (2007) argue that, in practice, few companies systematically integrate scenario planning and simulation into the planning process, mainly due to fear of the unknown, lack of time or lack of adequate training in developing scenario plans and techniques.

Though much is found about processes and tools for building scenarios, little is known about the outcomes and the experience of actually using them, namely on the effects of scenario planning on company performance and competitiveness (O'Brien, 2004; Varum and Melo, 2010). Exceptions are perhaps the scenario planning frameworks that, just like SRA / ERM frameworks (see 2.2.3), have extended to national or regional levels, in order to support public policy. Initially focusing on technology or security fields, countries like the United Kingdom, the Netherlands, Finland, France, as well as Canada, Australia, New Zealand, Singapore and Japan have realized single-issue focus is in many instances insufficient, and, consequently, they have started cutting across the traditional boundaries of policy areas and government departments (Habegger, 2010), with the United Kingdom (UK), Singapore, and the Netherlands being at the vanguard of this trend (Habegger, 2010).

2.3.2 Review of scenario planning approaches

Before progressing further with the literature review on scenario planning approaches, it is essential to clarify some of the specific lexicon adopted by futures experts, such as *trends*, *drivers of change*, *wild cards/shocks*, *discontinuities* and *weak signals*. Given the wide variety of existing definitions (Kuosa, 2011; Saritas and Smith, 2011), Saritas and Smith (2011) suggest one single definition for each concept, considered by them as the most applicable after exploring the different perspectives:

- *trends* are "somewhat gradual forces, factors and patterns that are pervasively causing change in society generally; the speed of change may be deemed comparatively slow or fast depending upon one's vantage point, but the important aspect of a trend is its pervasiveness". When trends expand over a generation (e.g. climate change) they can be considered *mega-trends;*
- *drivers of change* (also referred to as *factors of change*) are "those forces, factors and uncertainties that are accessible by stakeholders and create or drive change within one's business or institutional environment; these (…) have real leverage on one's future flexibility and outcomes – i.e. if a driver goes one way or the opposite way the real divergence occurs and change patterns evolve differently" (e.g.: policy or regulatory changes);
- *wild cards/shocks* are "those surprise events and situations which can happen but usually have a low probability of doing so – but if they do their impact is very high. These situations tend to alter the fundamentals, and create new trajectories which can then create a new basis for additional challenges and opportunities that most stakeholders may not have previously considered or prepared for" (e.g. nuclear bomb). Another expression that often arises is *black swans*, which is seemingly close to *wild cards* but refers to "extremely rare events that have never been encountered before (to the best of the observer's knowledge) and in principle, cannot be anticipated" (Paté-Cornell, 2012).
- *discontinuities* refer to "rapid and significant shifts in trajectories without the aspect of being mostly unanticipated or deeply surprising (…) and fundamentally alters the previous pathways or expected direction of

policies, events and planning regimes" (e.g.: abrupt breakdown and decrease in an historical growing demand);

- *weak signals* are "the early signs of possible but not confirmed changes that may later become more significant indicators of critical forces for development, threats, business and technical innovation. They represent the first signs of paradigm shifts, or future trends, drivers or discontinuities" (e.g. in the 1980s the first mention was made of global warming and climate change).

There have been many attempts to define a typology that facilitates the overview of the different structured methodologies for scenario development. In fact, typologies help in establishing a common language among researchers, which, in turn, improves the communication, the understanding, the comparison and the development of methods (Börjeson *et al*., 2006). Despite all the attempts, consensus has not been reached (Börjeson *et al*., 2006) and there are presently so many typologies that some authors describe it as 'methodological chaos' (Martelli, 2001 and Bradfield *et al.*, 2005 in Amer *et al.*, 2013) or "scenarios fuzziness" (Goeminne and Mutombo, 2007), which is reflected in the large number of different and at times conflicting definitions, characteristics, principles and methodological ideas about scenarios (Bradfield *et al.*, 2005) – see Table 2-1. This might perhaps explain the emergence, in recent years, of a number of academic reviews and surveys describing the current status of the body of literature and knowledge on scenario planning (e.g. Bradfield *et al.*, 2005; Börjeson *et al*., 2006; Varum and Melo, 2010; Kuosa, 2011; Saritas and Nugroho, 2012; Amer *et al.*, 2013).

Table 2-1 – Examples of scenario planning typologies

Typology	Author	Source
Habermas' technical, hermeneutic/practical and emancipatory.	Sandberg, 1976; Mannermaa,1986; and Slaughter, 1988	(Börjeson *et al*., 2006)
Possible, probable and preferred.	Amara, 1981	(Kuosa, 2011; Börjeson *et al.*, 2006)
Predictive, interpretive, critical and action learning.	Inayatullah, 1990	(Kuosa, 2011)
Colonizing and decolonizing.	Sardar, 1993	(Kuosa, 2011)
Extrapolation, utopian and vision.	Masini, 1993	(Börjeson *et al*., 2006)
Individual vs social and external vs internal	Wilber, 1995	(Amer *et al.*, 2013)
Possible, realizable and desirable	Godet and Roubelat, 1996	(Goeminne and Mutombo, 2007)
Continued growth, collapse, steady state and transformation.	Dator, 2002	(Amer *et al.*, 2013)
Identifying present trends, panoramic view and questioning all the others.	Marien, 2002	(Börjeson *et al*., 2006)
Comtean positivism, optimistic humanism, pluralistic humanism, polling democracy, critical pragmatism, relativistic pragmatism and democratic anarchism.	Tapio and Hietanen, 2002	(Börjeson *et al*., 2006)
Process goal (why?) - explorative or decision support, process design (how?) - intuitive or formal and scenario content (what?) - complex or simple	van Notten *et al.*, 2003	(Börjeson *et al*., 2006)
Creation of future images and visions; ability to support planning and decision making; to solve the great global questions of all humankind.	Borg, 2003	(Kuosa, 2011)
Predictive, eventualities and visionary.	Dreborg, 2004	(Börjeson *et al*., 2006)
Subjectivist, realist and critical.	Bell, 2005	(Kuosa, 2011; Börjeson *et al*., 2006))
Technical, organizational and personal.	Linstone, 2007	(Kuosa, 2011)
Preferred, disowned, integrated and outlier.	Inayatullah, 2008	(Amer *et al.*, 2013; Börjeson *et al.*, 2006)

Regardless of the number of existing typologies, it is worth noting they all share a common sequence of steps for scenario building. Though the number of steps varies from author to author (e.g. O'Brian, 2004, Ogilvy and Schwartz, 2004 in Goeminne and Mutombo, 2007; Gausemeier *et al.*, 1998 in Saritas and Nugroho, 2012), due to differences in the respective detail, they may be synthesized as follows:

i. Identification of a focal issue or decision to be taken (Amer *et al.*, 2013; Goeminne and Mutombo, 2007; Brummell and MacGillivray, 2008): "What are the central concerns and key issues of the users of the scenarios?"
ii. Scenario development. This includes gathering and analysing information about what is important for an organisation to understand future uncertainties; and developing a consistent and plausible set of descriptions of possible futures, or scenarios, through the use of a structured methodology.
iii. Evaluation of the implications of the scenarios for the organisation, i.e., the scenario transfer to the decision-field (O'Brian, 2004; Saritas and Nugroho, 2012).

Taking up van Notten *et al.* (2003), the literature review will now proceed by framing it around the three questions: "why?", "how?" and "what?".

<u>The "why-question"</u> is related to the purpose of the scenario building exercise – and hence, with the focal question. The typology proposed by Börjeson *et al*. (2006) is considered by several authors as one of the most prevalent for scenarios categorizing (Varum and Melo, 2010). Establishing a rough correspondence with Amara's "probable, possible and preferred", Godet's "realizable, possible and desirable", or Dreborg's "predictive, eventualities and visionary", Börjeson *et al*. (2006) classified scenarios as *predictive*, *explorative* and *normative*, respectively, which, in turn, sub-divide into two categories each (Figure 2-3).

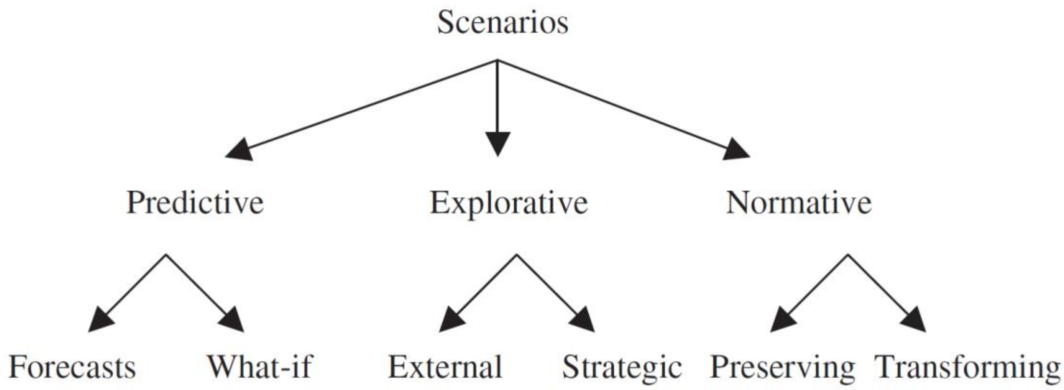

Figure 2-3 – Scenario typology proposed by Börjeson *et al*. (2006)

The *predictive* mode of thinking attempts to anticipate what will happen by trying to find the most likely development in the future, in order to be better prepared, and usually lies on historical trends, extrapolating them into the future under probable (forecasts) or not so likely (what-if) circumstances (Börjeson *et al*., 2006). The *explorative* mode of thinking is based on the assumption that it is impossible to predict what will actually happen. As such, it considers several possible external (trends or mega-trends) and/or strategic (internal drivers of change) events which will convey a set of scenarios corresponding to different developments, being most useful for mid and long-term strategic planning (Börjeson *et al*., 2006). Finally, the *normative* mode of thinking is intended to devise a new, better way for society or some sector or activity to function in the future – the main challenge will be discerning how the transition from the present should be made in order to achieve that desirable future, either preserving or transforming the normative starting points (Börjeson *et al*., 2006).

Although this topology provides a basis for structuring scenarios approaches, there is a tendency for actual studies to become compound or 'hybrids', combining the three modes of thinking in different degrees (Robison, 2003 in Börjeson *et al*., 2006; Goeminne and Mutombo, 2007), the Intergovernmental Panel on Climate Change, IPCC, Special Report on Emissions Scenarios, SRES (2007), being a paradigmatic example.

The "how-question" addresses the tools and techniques that can be used in scenario development. Three schools stand out as being widely recognized, two of them Anglophonic - "intuitive logics" and "probabilistic modified trends (PMT)" – and the other French – "La prospective" (Bradfield *et al*., 2005; Varum and Melo, 2010; Amer *et al.,* 2013). According to Bradfield *et al.* (2005), "intuitive logics" is the dominant school in the USA and many other countries. It assumes that business decisions are based on a complex set of relationships among the external factors (political, economic, social, etc.), and scenarios are drawn upon a hypothetical sequence of events, based on qualitative methods (Amer *et al.,* 2013). "PMT" builds on the assumptions that traditional trend analysis does not incorporate unprecedented future events and, on the other hand, that it is unrealistic to forecast an event in isolation without considering occurrence of other key impacting events (Bradfield *et al.*, 2005). Hence, it uses two different matrix based techniques, disseminated by a range of proprietary methodologies: the Trend Impact Analysis, TIA, and the Cross Impact Analysis, CIA, in order to probabilistically modify the extrapolated trends (Bradfield *et al.*, 2005). "La Prospective" is a French school initially assuming that the future can be deliberately created and modelled, thus giving way to normative, visionary scenarios. Later on, the concept was expanded to make this school suitable for "strategic scenario building", using not only qualitative but also quantitative methods, including morphological analysis for scenario building, and a range of computer programs were developed for identifying key variables, analysing actors' strategies and determining the probability of scenarios (Bradfield *et al.*, 2005). As a result, Bradfield *et al.* (2005) describe this school as a blend of both intuitive logics and PMT' methodologies.

Table 2-2 presents a comparison between the main features of each of the three schools (Bradfield *et al.*, 2005).

Table 2-2 - Comparison of the salient features of the three schools of scenario techniques (Bradfield *et al.*, 2005)

	Intuitive-Logics Models	*La Prospective* Models	Probabilistic Modified Trend Models
Purpose of the scenario work:	Multiple, from a once-off activity making sense of situations and developing strategy, to an ongoing activity associated with anticipation and adaptive organisational learning.	Usually a once-off activity associated with developing more effective policy and strategic decisions and tactical plans of action.	A once-off activity to enhance extrapolative prediction and policy evaluation.
Scenario perspective:	Descriptive or normative.	Usually descriptive, can be normative.	Descriptive.
Scope of the scenario exercise:	Can be either broad or narrow scope ranging from global, regional, country, industry to an issue specific focus.	Generally a narrow scope but examination of a broad range of factors within the scope.	Narrow scope focused on the probability and impact of specific events on historic trends.
Scenario horizon year:	Varies: 3–20 years.	Varies: 3–20 years.	Varies: 3–20 years.
Methodological orientation:	Process orientation - inductive or deductive, essentially subjective and qualitative in approach relying on disciplined intuition.	Outcome orientation - directed and objective, quantitative and anlytical approaches (with some subjectivity) relying on complex computer-based analysis and mathematical modeling.	Outcome orientation-directed and objective, quantitative and analytical approaches (with some subjectivity) using computer-based extrapolative forecasting and simulation models.
Nature of scenario team participants:	Internal - scenarios developed by a facilitated from within the organization.	Combination of some key individuals from within the organization led by an expert external consultant.	External - scenario exercise undertaken by expert external consultants.
Role of external Expters:	Experienced scenario practitioner to design and facilitate the process; periodic use of remarkable people as catalysts of new ideas.	Dominant - expert-led process using an array of proprietary tools to undertake comprehensive analysis and expert judgments to determine scenario probabilities.	Dominant - expert-led process using proprietary tools and expert judgments to identify high impact unprecedented future events and their probability of occurrence.
Tools commonly used:	Generic - brainstorming, STEEP analysis, clustering, matrices, system dynamics and stakeholder analysis	Proprietary - structural (Micmac) and actor (Mactor) analysis, morphological analysis, Delphi, SMIC Prob-Expert, Multipol and Multicriteria evaluation.	Proprietary Trends Impact and Cross Impact Analysis, Monte Carlo simulations.
Scenario starting point:	A particular management decision, issue or area of general concern.	A specific phenomenon of concern.	Decisions/issues for which detailed and reliable time series data exists.

Identification/selection of key driving forces:	Intuition - brainstorming techniques, analysis of STEEP factors, research, and discussion with remarkable people.	Interviews with actors involved in the phenomenon being studied and comprehensive structural analysis using sophisticated computer tools.	Fitting curves to historical time series data to identify trends and use of expert judgment to create database of potential high impact unprecedented future events.
Establishing the scenario set:	Defining the scenario logics as organizing themes or principles (often in the form of matrices).	Matrices of sets of probable assumptions based on key variables for the future.	Monte Carlo simulations to create an envelope of uncertainty around base forecasts of key indicators.
Scenario Exercise Output:	Qualitative - set of equally plausible scenarios in discursive narrative form supported by graphics, some limited quantification. Implications, strategic options and early warning signals increasingly a part of scenario output.	Quantitative and qualitative - multiple scenarios of alternative futures supported by comprehensive analysis incorporating possible actions and their consequences.	Quantitative - baseline case plus upper and lower quartiles of adjusted time series forecasts. may be embellished by short storylines.
Probabilities attached to scenarios:	No, all scenarios must be equally probable.	Yes, probability of the evolution of variables under assumption sets of actors' behaviour.	Yes, conditional probability of occurrence of unprecedented and disruptive future events.
Number of Scenarios generated:	Generally 2–4.	Multiple.	Usually 3–6 dependent on the number of simulations.
Scenario evaluation criteria:	Coherence, comprehensiveness, internal consistency, novelty - underpinned by rigorous structural analysis and logics. All scenarios equally plausible.	Coherence, comprehensiveness, internal consistency - underpinned by rigorous structural and mathematical analysis; plausible and verifiable in retrospect.	Plausible and verifiable in retrospect.

As mentioned above and is patent in Table 2-2, existing techniques range from qualitative, to semi-quantitative and quantitative.

Quantitative methods are considered useful for narrowly focused projects having a short time horizon (Figure 2-4), and there is also a limited number of most frequent scenario planning approaches, namely Cross Impact Simulation, Interactive Future Simulations, Trend Impact Analysis and Fuzzy Cognitive Mapping (Amer *et al.*, 2013). On the contrary, qualitative methods are considered appropriate for projects having a large scope and long time horizon, and a wide dispersion of methods exists, like surveys, workshops and Delphi for data generation (Börjeson *et al*., 2006) – some even argue that "there are almost as many ways of developing scenarios as there are practitioners in the field" (Bradfield *et al.*, 2005). Despite these differences, both qualitative and quantitative approaches can be complementary and, when used together, strengthen each other (Amer *et al.*, 2013).

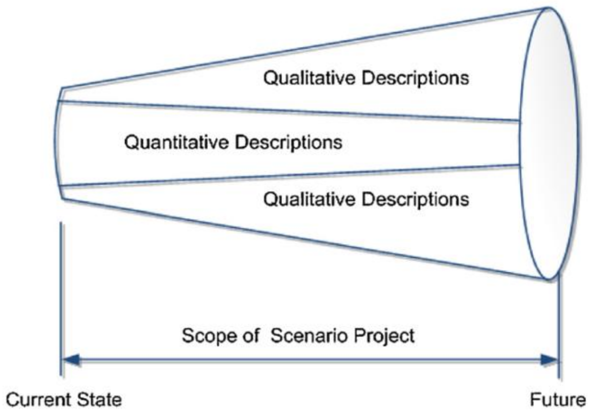

Figure 2-4 - Time horizons for qualitative *versus* quantitative scenario analysis (Pillkahn, 2008 in Amer *et al.*, 2013)

Finally, the "what-question" refers to the content of the scenarios, namely whether these are complex or simple, what is the appropriate number of scenarios to be built and how these can be validated.

The complexity of a scenario framework is associated with the number of driving forces to be considered, based on which Pillkahn (2008 in Amer *et al.*, 2013) suggests three approaches: minimal, standard and maximum (Table 2-3).

Table 2-3 - Three approaches to drafting the scenario framework (Pillkahn, 2008)

	Minimal Approach	**Standard Approach**	**Maximum Approach**
Number of Uncertainties	2	Around 3 to 8	>8
Deployed Tools and Methods	Four-quadrants (Axis of Uncertainty) matrix.	Wilson matrix, morphological analysis.	Wilson matrix morphological analysis, cross-impact analysis, consistency analysis.
Application	Simple description of the enquiry.	Description of the inquiry with a manageable number of uncertainties and elements.	Complex subjects with many degrees of freedom and unknown variables.

Given the inherent uncertainty of the future, developing multiple scenarios is a common practice, especially in the field of strategic development so that strategies or plans can be tested in terms of their robustness against a set of possible futures (O'Brien, 2004). As there are an infinite number of stories about the future, the challenge is to focus on those stories that are important (Saritas and Nugroho, 2012), and the appropriate number should be neither too small (less than three), so that no important situation is left out from the analysis, nor too big, otherwise the process dissipates (Amer *et al.*, 2013). Thereby, Amer *et al.* (2013) examined the recommended number of scenarios by several authors and concluded that considering three to five future scenarios is appropriate for a scenario project.

As in many other fields, scenario development should be subject to validation at the end of the process. Despite some scenario evaluation criteria already being highlighted in Table 2-2, it is worth noting that Amer *et al.* (2013) analysed the scenario validation criteria proposed by different authors, which led to the conclusion that *consistency* and *plausibility* are the decisive conditions for assessing scenarios as credible and valid.

2.3.3 Using scenarios for strategic planning in water utilities

Future scenarios have been used to inform strategic planning in water utilities mostly in isolation, i.e., focusing on a single specific issue - e.g.: demography, consumption habits, water quality at sources, behaviour of infrastructures, climate change - and, not rarely, based on extrapolation of past trends (Means *et al.*, 2010; Cosgrove, 2013). Whilst trend extrapolation may be used for the short-term, it has been recognized that this method does not apply for the long-term (Figure 2-4), because of both the effects of unprecedented future events and the high levels of uncertainty around the evolutionary trends and drivers of change (Means *et al.*, 2010; Bradfield *et al.*, 2005).

Global scenarios for climate change have been developed in recent years (IPCC, 2007), thus enabling water utilities to delineate long-term adaptation strategies. In fact, any significant change in precipitation and temperature patterns will impact the dynamics of the existing systems, and many water utilities are now addressing the challenge of adapting themselves to the effects of climate change. The basis of these scenarios' uncertainty is threefold: (i) the unknown future concentrations of greenhouse gases and other anthropogenic or natural forcing agents (e.g. injections of stratospheric aerosol from explosive volcanic eruptions); (ii) the unknown natural (unforced) climate variations; and (iii) the errors associated with the predictive models (Collins *et al.*, 2006). To overcome these problems, modellers tend to use a wide array of climate change scenarios that will then bind a range in the precipitation and temperature patterns. Having obtained the results of the climate change scenarios, the correspondent vulnerability of water supply systems is subsequently assessed, using either quantitative techniques, such as precipitation-runoff models, water quality modelling, etc., or qualitative and less formal approaches. As each meteorological variable presents its own impacts to the system, considering the synergetic effect of the simultaneous change in all the variables represents a challenge for water utilities. Conversely, adaptation measures (e.g.: water sources diversification, water reuse, changes in the operation, etc.) are often embedded among other objectives rather than climate change adaptation, such as improving water efficiency or the overall resilience of the system.

While territorial plans and measures may dictate the course of land use and demography for the short term, when it comes to the long term, it is not possible to anticipate what will happen (Environment Agency, 2009; Environment Agency, 2011; Aguiar and Santos, 2007), so the usual approach consists of setting a series of scenarios to describe possible futures. As land use and demography are generally only two of the variables that contribute to setting consistent futures of the global environment, they are integrated in most of the major global scenarios studies, such as IPCC (2007) SRES, the Global Environment Outlook and the Millennium Ecosystem Assessment (Vuuren *et al*., 2007). Land use surveys at a national scale, based on satellite images, such as Corine Land Cover (European Environment Agency, 2006), and local demographic statistics and projections, based on census data and migration flows, provide a local input to which the global scenarios' trends may be applied. Alternatively, local scenarios may be specifically developed, as it is the case of the work carried out by the Environment Agency for England and Wales (Environment Agency, 2009; Environment Agency, 2011). These scenarios are then used by water utilities, as, on the one hand, land use changes are mostly associated with perturbations of the raw water quality and availability (Weatherhead and Howden, 2009); on the other hand, demographic changes represent a pressure not only on the water sources' quantity, but also on water sources' quality, due to an increase in point source pollution. Adaptation and mitigation measures include reinforcement of the treatment schemes, the re-utilisation of water, the setting or increasing of demand management policies (in contrast with resource development) and the reinforcement of the agriculture and forestry practices monitoring (Weatherhead and Howden, 2009).

Perhaps because of the aforementioned global environmental scenarios, Kuosa (2011) believes that "environmental futures studies have been evolving in their own path for years, and it will be considered as an ''independent field'' in coming years, or it will be adopted to some formal discipline (…). I guess, it will not end up to be a part of the third paradigm of futures studies, as almost all of its ontology, epistemology, argumentation and objectives base on different type of thinking. It is merely a future-oriented extension to Management thinking".

2.4 Linking Risk and Futures

2.4.1 Overview

As outlined in the previous chapter, both strategic risk management and future scenarios are aimed at supporting strategic planning, the respective use being taped by the extent of knowledge about likelihood and consequences. Figure 2-5 shows that scenarios concentrate only on projected consequences, thus missing the link with risk management in the future due to the unaccounted perspective of the projected likelihood.

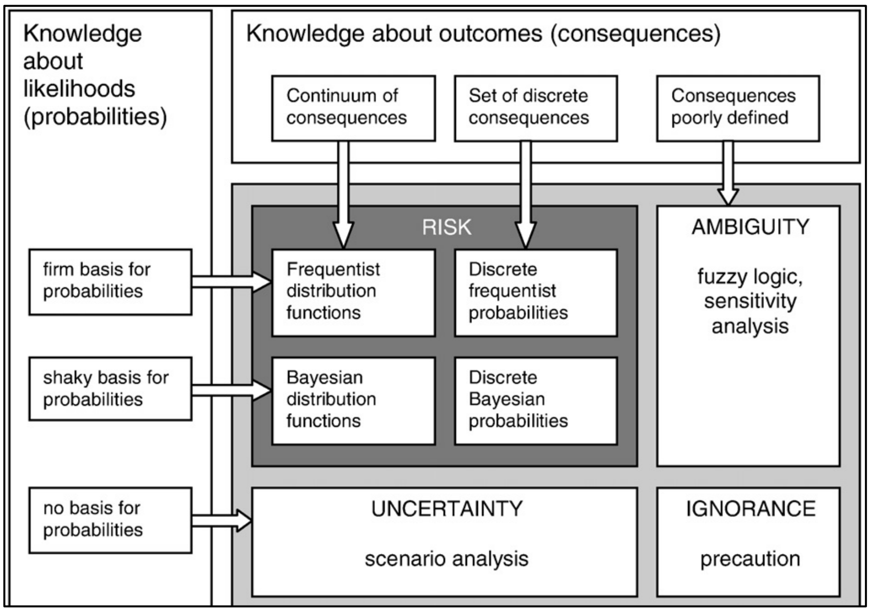

Figure 2-5 - Categorising incertitude within environmental decision making (redrawn from Stirling, 2001, in Pollard *et al.*, 2008)

Nonetheless, these two areas of research share many commonalities, as pointed out by Koivisto *et al.* (2009):

- they consider similar development phases: problem formulation / focal question; risk evaluation / scenario building; risk acceptation and options appraisal / implications of the scenarios for the organization and strategic actions appraisal;
- they stem from a knowledge making process, which means a common theoretical ground – both approaches organise the knowledge making from personal and proprietary to common sense and public, making the developed knowledge more than the sum of its elements.

Therefore, these two research traditions are somehow interrelated, but in practice the respective research projects have separated and are seldom linked (Koivisto *et al.*, 2009).

2.4.2 Attempts to link risk and futures

Linking strategic risk and futures' assessments may have mutual advantages. In fact, strategic risks should be assessed within a more holistic approach like the ones in futures' assessments, while the latter would benefit from the systemic framework that is usually associated with the former (Koivisto *et al.*, 2009). Based on these assumptions, Koivisto *et al.* (2009) developed the only research known so far aiming at identifying possible synergies between risk and future assessments, which is focused on technological development. From the analysis of three different projects, they came to the following conclusions:

- the INNORISK project[2] is the one where integration of futures and risk assessment traditions will be profitable, or, at least, easier to carry on, since it focuses on corporate strategic decision making, thus sharing longer time frames - whereas for the other projects, the narrow time horizon of risk analysis contrasted with the large scale of futures development;
- due to the need to develop more holistic risk management processes responding to the continuous change, the future risk assessment shows up as a methodology that should increasingly adapt supplementary elements from many different approaches;
- the two main benefits in integrating risk and futures approaches are: the openness to new future possibilities by changing mind-sets, building trust among actors and developing better preparedness for the change; and the generation of knowledge, by creating an understanding and sharing it in networks of people.

Koivisto *et al.* (2009) end up saying that in practice, “to succeed to build the solid bridge between the foresight and risk analysis methods new case studies would be needed”.

2.5 Summary, insights and gap analysis

It is clear that SRA constitutes a challenge for water utilities. From an organizational context, most companies have not yet reached their highest level

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[2] The focus of the INNORISK project is on the opportunity recognition and management of future uncertainties and risks in companies that are giving rise to new business, by introducing existing technologies into new markets, development of new technologies for existing markets, or creation of new technologies in new markets. The INNORISK project includes three stages: opportunity recognition, conceptualisation and commercialisation. Foresight and risk assessment are essential parts of each stage.

of maturity, where they would be capable of learning and adapting continuously, hence building a risk culture within organizations is still required. In particular, implementing the right mechanisms for information to flow across business units is seen as fundamental for preventing risk from being managed in silos. From a methodological point of view, the need for current ERM approaches to assess risks in a more integrated way – either by addressing both environmental and business risks or by capturing their interconnections – has been recognized. The importance of long-term evaluation of strategic risks has also been noted, though there is little evidence that this has been done before in an integrated way.

Future scenarios are actually a very fragmented field of research. Notwithstanding this, a broad alignment between three blocks, expressed in Table 2-4, is suggested by the literature review herein undertaken, though there is a growing tendency for these to become "hybrid".

Table 2-4 – Alignment of scenario planning features

	Block 1	**Block 2**	**Block 3**
Purpose	Predictive	Explorative	Normative
School	Probabilistic modified trends	La prospective	Intuitive logics
Type of methods	Quantitative	Semi-quantitative	Qualitative

Scenario planning has been used as a strategic tool, just like ERM, but in water utilities they generally focus on one single issue and often develop from extrapolations of past trends, which were shown to be unsuitable for long-term analysis.

Risk management and scenario planning evidence many commonalities: besides the ones already pointed out by Koivisto *et al.* (2009) – considering similar development phases and stemming from a knowledge making process – the literature review shows that, additionally,

- they both support long-term planning;

- national frameworks for both SRA and Futures have been developed, with the UK and the Netherlands in leading positions in both fields;
- both use quantitative, semi-quantitative or qualitative methods, and usually assessments comprise a mix of existing techniques;
- they both contribute to opening “mental maps” of managers and to initiate new conversations among the different actors;
- in the water business, the majority of both approaches lack the integrated perspective underlying the complexity of water supply systems’ management.

Despite these similarities, risk and futures research have run in parallel, and only one attempt to link them has been found, though not in the water context.

In short, current limitations of SRA and scenario planning in water utilities are mainly related to the need to evolve to a more integrated approach (in terms of the risks and drivers considered as well as of the respective interconnections) and to establish a culture of knowledge sharing and generation within organizations. Even though strategic risks are long-term changing risks, and despite the similarities between strategic risk management and future scenario planning, the link between these two areas of research has seldom been established, and no attempt has been found for the water sector.

3 RESEARCH QUESTION, AIM AND OBJECTIVES

The research question is based on the premise that a holistic approach linking strategic risk analysis with future scenario planning in water utilities would fill the gaps identified in the state-of-the-art of strategic risk management. The assumption is that such approach would lead to more efficient corporate management, unveiling tacit knowledge and allowing strategic objectives to be proactively managed. Thus, the research question asks:

How can a holistic approach linking strategic risks assessment and future scenario planning in water utilities be set up?

The overarching aim of this study is therefore to develop and test a novel approach that allows the Board of water utilities to appraise strategic risks and to gain a long term perspective on this baseline set of risks, while stimulating the pervasiveness of a risk culture within the organization.

In order to achieve this aim, a number of objectives need to be reached:

- To examine the existing methodologies for SRA in order to detect the gaps to be filled and the benefits to be expanded;
- To investigate how the company's team (members of the Board, risk experts and risk managers) shall be assembled and involved throughout the process so that they gain ownership over it;
- To explore how strategic objectives shall be identified;
- To construct a holistic, systemic model to assess strategic risks in the present (baseline);
- To investigate how the futures' science can be interconnected with SRA;
- To undertake the construction of future scenarios and to reassess strategic risks in the future;
- To develop a way of presenting baseline risks assessment as well as the way risks will change in the future to the Board.

4 THEORETICAL APPROACH

4.1 Research paradigm

4.1.1 Overview

This thesis is governed by the philosophical approach of action-centred research, which draws on the critical realism theory. In this type of research, a hypothesis and theory are not developed prior to the research, but rather arise during the course of the analysis. In the end, the aim is for analytic generalization, rather than statistic generalization (as it would be the case of positivism).

To make sense of the data and to generate new theory, reasoning is made through combinations of inductive and deductive thinking, throughout the different stages of the research. Particularly, as the research question can be broken down into two sequential questions:

(i) *how can an integrated strategic risk assessment be set up?*

(ii) *is it possible to reassess baseline risks within the context of future scenarios? how?*

several methods have been applied, namely brainstorming, expert elicitation/workshops, interviews and document analysis, semi-quantitative risk matrices, cognitive mapping and morphological analysis – these will be further detailed in chapter 6. Underlying each of these methods, different analytical and synthetic strategies have been followed, such as memoing, drawing of integrative diagrams and writing of narratives.

4.1.2 Critical realism

The term “critical realism” was introduced in 1975 by Roy Bhaskar, building on earlier work in realist philosophy of science, particularly that of Rom Harré (Sayer, 2000). “Critical realism” is one of the three main traditions in the philosophical foundations of warranted knowledge or theory (Table 4-1), following a subjectivist epistemology (how we come to know social reality), similar to the hermeneutic tradition, but an objectivist ontology (the nature of social reality), like the positivists (Johnson and Duberley, 2000).

Table 4-1 – Philosophical foundations of research traditions (Coghlan and Brannick, 2005)

Philosophical foundations	Positivism	Hermeneutic and postmodernism	Critical realism and action research
Ontology	Objectivist	Subjectivist	Objectivist
Epistemology	Objectivist	Subjectivist	Subjectivist
Theory	Generalizable	Particular	Particular
Reflexivity	Methodological	Hyper	Epistemic
Role of researcher	Distanced from data	Close to data	Close to data

Neuman (2003) described critical realism as “a critical process of inquiry that goes beyond surface illusions to uncover the real structures in the material world in order to help people change conditions and build a better world for themselves”. The implications implicit in this description are three-fold.

First, this ontological perspective is built around the “real” – the structure and causal powers of the object; the “actual” - what happens if and when those powers are activated; and the “empiric” - the domain of experience, in the sense that powers may exist unexercised, and hence that what has happened or been known to have happened does not exhaust what could happen or have happened (Bhaskar, 1975 in Sayer, 2000). This notably applies to the strategic risk management and scenario planning fields, wherein, on the one hand, quantitative methods (used by positivists) are generally criticized for relying on past trends that do not take into account possible events that did not happen in the past; and, on the other hand, risk evaluation has more to do with the *actual/empiric* perception of risk (Renn, 2008b; Slovic, 1987*)* rather than with the *real* risk.

Secondly, realist ontology also acknowledges the dimension of change, since the nature of the real objects is seen as capable of enabling what can happen whilst not pre-determining what will happen – making it possible, therefore, to understand how objects could be or become things which currently they are not (Sayer, 2000). Commitment to change and democratic engagement are the principles that guide self-reflexivity, which leads to emancipation (Sayer, 2000).

Finally, the analysis of causation appears as one of the most distinctive features of realism (Sayer, 2000), which should not be understood as the model of regular successions of events, where the proof would be made by gathering data on regularities or repeated occurrences – "what causes something to happen has nothing to do with the number of times we have observed it happening" (Sayer, 2000); but, instead, as identifying causal mechanisms and how they work, and discovering if they have been activated and under what conditions (Sayer, 2000).

4.1.3 Action research

Action research is founded in the work of Kurt Lewin, who describes the scientific approach as a "collaborative cyclical process of diagnosing a change situation or a problem, planning, gathering data, taking action, and then fact-finding about the results of that action in order to plan and take further action" (Lewin, 1946 and Dickens and Watkins, 1999 in Coghlan and Brannick, 2005). It has been used in education, business organizations and health contexts in particular (Wisker, 2008), involves a relationship between researcher and client/colleagues and is aimed at both solving a problem and generating new knowledge (Coghlan and Brannick, 2005) – a description that directly applies to this research work, as explained in chapter 1.2. Gummesson (2000, in Coghlan and Brannick, 2005) further details this definition, by enumerating the following characteristics of action research:

(i) Action researchers take action;

(ii) Action research always involves two goals: solve a problem and contribute to science;

(iii) Action research is interactive, requiring cooperation with client /colleagues;

(iv) Action research is aimed at developing holistic understanding during a project and recognizing complexity - action researchers need to have a broad view of how the system works and be able to move between formal structural and technical and informal people subsystems;

(v) Action research is fundamentally about change;

(vi) Action research requires an understanding of the ethical framework, values and norms within which it is used in a particular context;

(vii) Action research can include all types of data gathering methods, namely qualitative and quantitative;

(viii) Action research requires a breadth of pre-understanding of the corporate or organizational environment, the conditions of business or service delivery, the structure and dynamics of operating systems and the theoretical underpinnings of such systems;

(ix) Action research should be conducted in real time - a live case study being written as it unfolds -, though retrospective action research is also acceptable;

(x) The action research paradigm requires its own quality criteria.

These characteristics allow an understanding of why action research is different from other scientific researches. Action researchers are actively involved with the subject of research, unlike traditional research. A distinction between theory and action is not postulated - 'there is nothing so practical as a good theory' (Lewin, 1951), though action research goes beyond the notion that theory can inform practice, to a recognition that theory can and should be generated through practice. Action research requires cooperation between the researchers and the client personnel, which involves three "voices" or "three persons" (Reason and Bradbury, 2001) corresponding to Reason and Marshall's three audiences of research: first-person is undertaken by individuals ("for me"); second-person is the involvement of the first with teams and between teams in interdepartmental groups ("for us"); and third-person is impersonal, referring to organizations ("for them"). The action researcher is expected to bring knowledge to the research project - as such, he is distinguished from researchers who, for example, think that all they have to do to develop grounded theory is just to go out into the field. Finally, action research should be judged by its quality and rigour, according to the criteria patent in Table 4-2, or, more shortly, conferring to three main elements: "a good story; rigorous reflection on that story; and an extrapolation of usable knowledge or theory from the reflection on the story" (Coghlan and Brannick, 2005).

Table 4-2 – Criteria to assess quality and rigour of action research projects

QUALITY (Reason and Bradbury, 2001)	RIGOUR (Reason, 2003 in Coghlan and Brannick, 2005)
Is the action research explicit in developing a praxis of relational participation? In other words how well does the action research reflect the cooperation between the action researcher and the members of the organization?	How you engaged in the steps of multiple and repetitious action research cycles (diagnosing, planning, taking action and evaluating were done), and how these were recorded to reflect that they are a true representation of what was studied.
Is action research guided by a reflexive concern for practical outcomes? Is the action project governed by constant and iterative reflection as part of the process of organizational change or improvement?	How you challenged and tested your own assumptions and interpretations of what was happening continuously through the project, by means of content, process and premise reflection, so that your familiarity with and closeness to the issues are exposed to critique.
Does action research include a plurality of knowing which ensures conceptual-theoretical integrity, extends our ways of knowing and has a methodological appropriateness?	How you accessed different views of what was happening which probably produced both confirming and contradictory interpretations.
Does action research engage in significant work? The significance of the project is an important quality in action research.	How your interpretations and diagnoses are grounded in scholarly theory, rigorously applied, and how project outcomes are challenged, supported or disconfirmed in terms of the theories underpinning those interpretations and diagnoses.
Does the action research result in new and enduring infrastructures? In other words, does sustainable change come out of the project?	

Having seen why action research differs from other scientific approaches, it is worth bringing up why it is different, as well, from regular practice – a point that may give rise to criticisms. Wisker (2008) advocates that, despite being based on practice, action research requires a more sustainable and explicit examination of decisions, relationships, evidences, data and learning that can be derived from practice. Knowledge generation results from the encounter between local insights and the understanding that the outsider brings to the table, in a Hegelian dialectic: an affirmation from one of the parties (the thesis) is brought forward and is met with demanding and challenging questions and counterpropositions (antithesis), and out of this friendly encounter of points of view (synthesis) will gradually evolve (Greenwood and Levin, 1988). In short, on-going critical analysis is the distinctive feature from just a mere new business process implementation (Wisker, 2008).

Main benefits of action research, as an alternative approach to traditional research, are related to the fact that it is practical, participative, emancipatory, interpretative and critical (Wisker, 2008). But perhaps the most important advantage is that pointed out by Zubber-Skerrit (1992 in Wisker, 2008) referring to higher education, but also applicable to other areas of research: it is a more effective and immediate way of improving practice while advancing knowledge – or, in other words, the fact that it avoids the need for the results to be implemented later.

From all of the above, it stands out that the relation of action research with the case-study approach is straightforward: the former is "the most demanding and far-reaching method of doing case study research" (Gummesson, 2000 in Coghlan and Brannick, 2005). This research focuses on one single in-depth case study (Yin, 2009), giving way to analytic rather than statistic generalization, as the adequacy of an analysis of a single case need have nothing to do with how many other such cases there are (Sayer, 2000).

4.2 Research design

The general outfit of the research design is that of an intensive research design (Table 4-3): it is strong on causal explanation and interpreting meanings in context, but as it tends to be very time-consuming, only one case was studied in-depth, in line with a practitioner action research.

Table 4-3 - Intensive and extensive research: a summary from Sayer (1992) in Sayer (2000)

	Intensive	Extensive
Research question	How does a process work in a particular case or small number of cases? What produces a certain change? What did the agents actually do?	What are the regularities, common patterns, distinguishing features of a population? How widely are certain characteristics or processes distributed or represented?
Relations	Substantial relations of connection.	Formal relations of similarity.
Type of groups studied	Causal groups.	Taxonomic groups.
Type of account produced	Causal explanation of the production of certain objects or events, though not necessarily representative ones.	Descriptive 'representative' generalizations, lacking in explanatory penetration.
Typical methods	Study of individual agents in their causal contexts, interactive interviews, ethnography, qualitative analysis.	Large-scale survey of population or representative sample, formal questionnaires, standardized interviews. Statistical analysis.
Limitations	Actual concrete patterns and contingent relations are unlikely to be 'representative', 'average' or generalizable. Necessary relations discovered will exist wherever their relata are present, for example, causal powers of objects are generalizable to other contexts as they are necessary features of these objects.	Although representative of a whole population, they are unlikely to be generalizable to other populations at different times and places. Problem of ecological fallacy in making inferences about individuals. Limited explanatory power.
Appropriate tests	Corroboration	Replication

Research design was modelled throughout the research, as it is typical of action research (Figure 4-1). In fact, despite main milestones having been set out in advance in a "general plan of action" (Wisker, 2008), many of the intermediate steps have been guided from the outcomes of the experimentation at EPAL, which led to new, subsequent reframing of the research design.

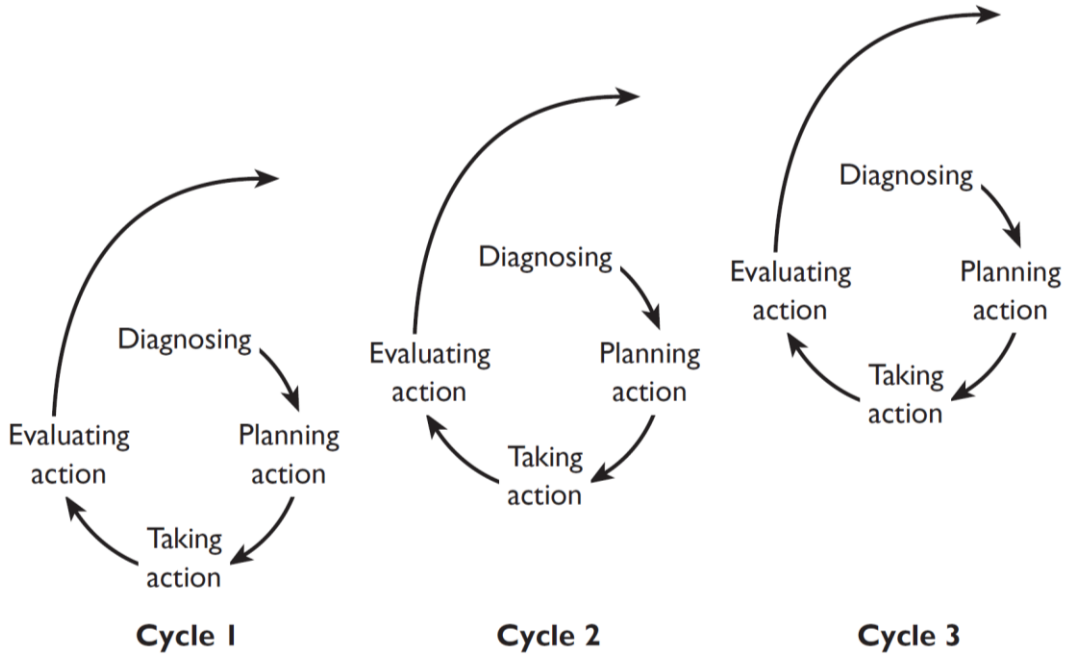


Figure 4-1 - Spiral of action research cycles (Coghlan and Brannick, 2005)

Referring back to the two parts into which the main research question may be divided, namely:

(i) *how can an integrated strategic risk assessment be set up?*

(ii) *is it possible to reassess baseline risks within the context of future scenarios? how?*

answering question (i) followed a similar approach to Prpich *et al.* (2011), which was based on a deliberative process through the following steps:

i. Assembly of the team (at EPAL) that would participate in the case-study;
ii. Identification of EPAL's strategic objectives;
iii. Analysis of strategic risks and presentation of the results.

Since action research is based on a collaborative process where “three persons” are involved, assembly of the team corresponds to setting out the “second-person”. This poses an important challenge as to who is involved in the research and how, because the quality of “second-person” inquiry and action is central to action research, given its collaborative and democratic characteristics (Coghlan and Brannick, 2005). Identification of EPAL’s strategic objectives corresponds to the “problem formulation” phase in risk analysis – “risk of what, to whom”. Finally, assessing strategic risks differs from the approach followed by Prpich *et al.* (2011), since cognitive mapping arose as the best way to build a systemic model of strategic risks, capturing the respective interactions.

Question (ii) involved the following additional steps:

iv. Gathering knowledge about mega-trends that will influence the future (climate change, land-use and demographic changes, natural deterioration of critical infrastructures, etc.) of EPAL’s business;
v. Construction of future scenarios;
vi. Systemic re-analysis of strategic risks in each scenario.

In fact, since one of the aims of this research is linking SRA and futures, the research design would have to include the construction of future scenarios, to which the knowledge of mega-trends is an important contribution. The objective of assessing baseline risks in future scenarios is to have a long-term perspective of their evolution under certain circumstances, which would support a better and more efficient strategic planning - the challenge here is to expand knowledge as to how this could be achieved.

Having completed and validated each of these steps, the response to the research question will be accomplished: the novel holistic approach linking strategic risks assessment and futures will be derived, as a whole, from the outcomes of each step; on the other hand, the engagement with and the pervasiveness of a risk management culture within the organization results, as a whole, from the process in itself.

4.3 Ethical considerations

Action research poses many ethical challenges to the researcher.

As a collaborative process, it challenges power relationships with hierarchies and personal relationships and assumptions with colleagues (Wisker, 2008). In fact, it is recognized that, ideally, those in power will support the research and embrace its outcomes (Wisker, 2008), but one potential problem that may arise is to what extent “support” can be understood as “interference”. In this work, the Board of EPAL was fully collaborative whilst not intrusive, thus facilitating the research. As for the colleagues, especially during the semi-structured interviews, care was taken to ensure the researcher was not compromising them when revealing information about their practices or views to the rest of the organization. Furthermore, a conscious attempt was made to direct the previous experience and insights of the researcher to the data gathering and the choice of the right questions, rather than to influence or bias the colleagues’ opinions.

A different issue has to do with the presentation of the results, which may include sensitive matters for the company. In order to deal with this problem, it was agreed that all the results would be expressed in the dissertation, as it is not subject to a “mass media” means of dissemination, but oral presentations or journal publications should express only carefully examined and selected information.

5 CASE STUDY CONTEXT

5.1 EPAL – Empresa Portuguesa das Águas Livres

5.1.1 Brief description and key figures

EPAL – Empresa Portuguesa das Águas Livres, SA, is the oldest and largest water supply company in Portugal, constituting the reference company within the water sector in Portugal. Founded in 1868 as CAL - Companhia das Águas de Lisboa, a privately owned concession to supply water to Lisbon, it became a state owned company in 1974, named EPAL. Since 1991, EPAL has been a public limited company, fully owned by Águas de Portugal group.

EPAL supplies wholesale quality water to approximately three million people (more than one-quarter of the Portuguese population) in 35 municipalities north of the River Tagus, corresponding to a total supply area of 7,090 km², as well as retail water to approximately 500 thousand inhabitants in Lisbon. With approximately 700 staff, EPAL has assets with a net fixed value of around 900 million EUR and a capital expenditure program of approximately 100 million EUR planned for the period 2014-2016. Over the last few years, EPAL has been generating profits of around 40 million EUR.

5.1.2 Water supply system

All the water sources are located in the Tagus River Basin, which is shared with Spain (see red and brown dots in Figure 5-1). About 90 per cent of the supply comes from Castelo do Bode reservoir, which, despite being situated in the totally Portuguese Zêzere river sub-basin, is shared with EDP (the Portuguese Company of Electricity) which owns the dam. Within this sub-system, water is treated at Asseiceira water treatment plant, WTP, through a scheme comprising mineralization coagulation/flocculation, flotation, oxidation (ozone), filtration and final disinfection (chlorine); built in 1987 with the capacity to treat 500,000 m^3/day, this WTP was enlarged and modified in 2007 to treat 625,000 m^3/day and to introduce flotation and ozonation into the treatment process. The second largest water source is the River Tagus, with abstraction undertaken at Valada. This water is pumped to Vale da Pedra WTP, which has a nominal capacity of

240,000 m^3/day and a treatment scheme comprising pre-chlorination, coagulation/flocculation, decantation, filtration and final disinfection (chlorine). Presently, an overall refurbishment of this WTP is being undertaken. The remaining sources are underground water sources: wells of Ota and Alenquer, located on a limestone massif; and boreholes of Lezírias, where the water is abstracted from the biggest aquifer in the Iberian Peninsula (Tejo-Sado aquifer) at depths of 250 m and 500 m.

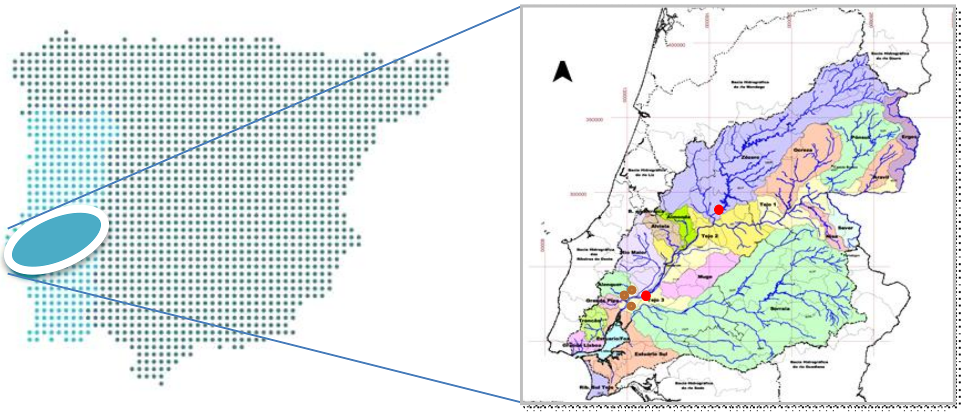


Figure 5-1 – Location of EPAL's water sources

Due to the enlargement of the system in 2007 and to the concomitant turn over observed in the historical increasing demand, the water supply system now evidences an overcapacity of drinking water production and transport.

The water supply system includes more than 2.100 kilometres of water mains, 37 pumping stations, 41 water tanks, 25 chlorination points and around 88.000 service connections (Figure 5-2).

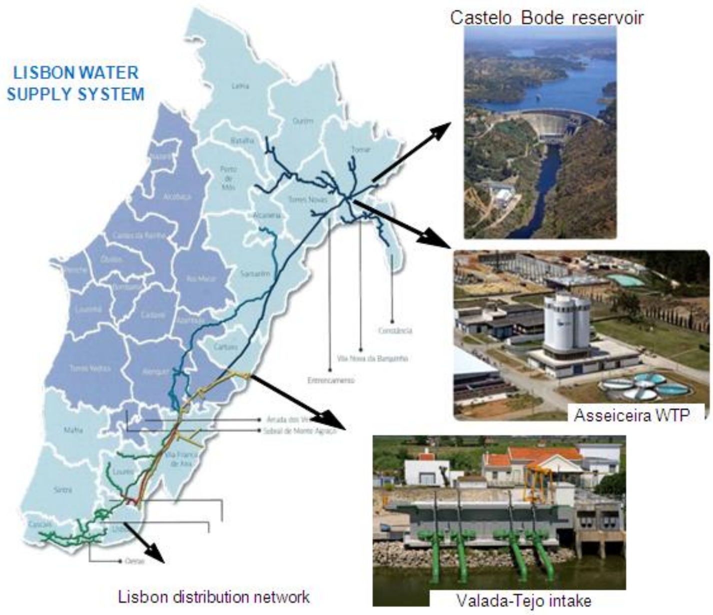
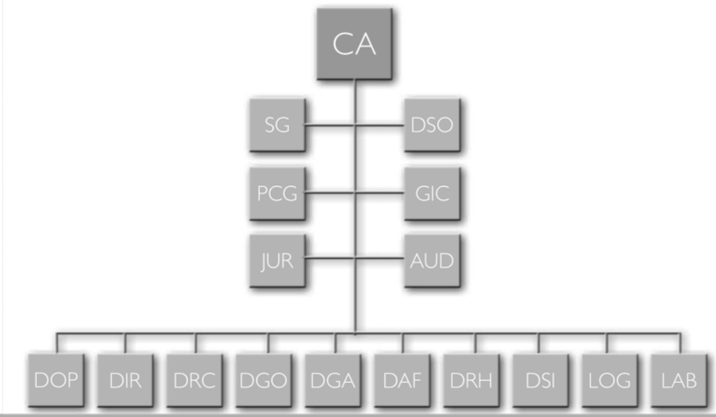


Figure 5-2 – EPAL's water supply system

5.1.3 Governance

Governance is assured by the following management bodies: (i) general council, whose only member is the holding company Águas de Portugal, that has the roles of evaluating and voting on the reports and the annual accounts, electing the members of the management bodies, deliberating on the statutes and capital increases, authorizing the acquisition and alienation of capital as well as the realization of investments worth more than 20% of the share capital; (ii) board of directors, composed of three members who are elected by the general council and are appointed for a three-year period, that may be renewed; (iii) supervision authority, which supervises the company and legally certifies the accounts; (iv) remuneration committee, which establishes the remuneration of the members of the management bodies; and (v) advisory council for the sustainable development, which sets out recommendations regarding the environmental sustainability of the company's activities.

Figure 5-3 presents the organizational structure of EPAL.



CA – Board of Directors			
SG - General Secretariat	DSO - Organizational development	AUD - Auditing	GIC – Image and Communication
JUR - Juridical affairs	PCG - Planning and management control	DOP - System Operation	DIR - Infrastructures maintenance
DRC - Customers relations	DGO - Projects and works	DGA - Asset management	DAF - Administrative and financial
DRH - Human resources	DSI - Information Systems	LOG - Logistics	LAB - Water quality control

Figure 5-3 – Organizational structure of EPAL

Economic regulation is carried out by DGAE, a directorate of the Ministry of Economy that annually celebrates a convention with EPAL for setting the tariffs, based on the following principles: (i) to assure an adequate remuneration of the capital invested; (ii) to assure adequate levels of self-financing; and (iii) to fully cover operational costs. Quality of service provided by EPAL is regulated and benchmarked by ERSAR, the National Water and Waste Regulator; in case any non-compliance with legislated parametric values of water quality is detected, it is reported to the Regional Health Administration (ARS-LVT) as well.

5.2 Assembled team

Following Prpich *et al.* (2011), the case-study team encompassed a risk co-ordinator / risk facilitator (the researcher), the management board, (senior) risk managers and risk experts – Figure 5-4.

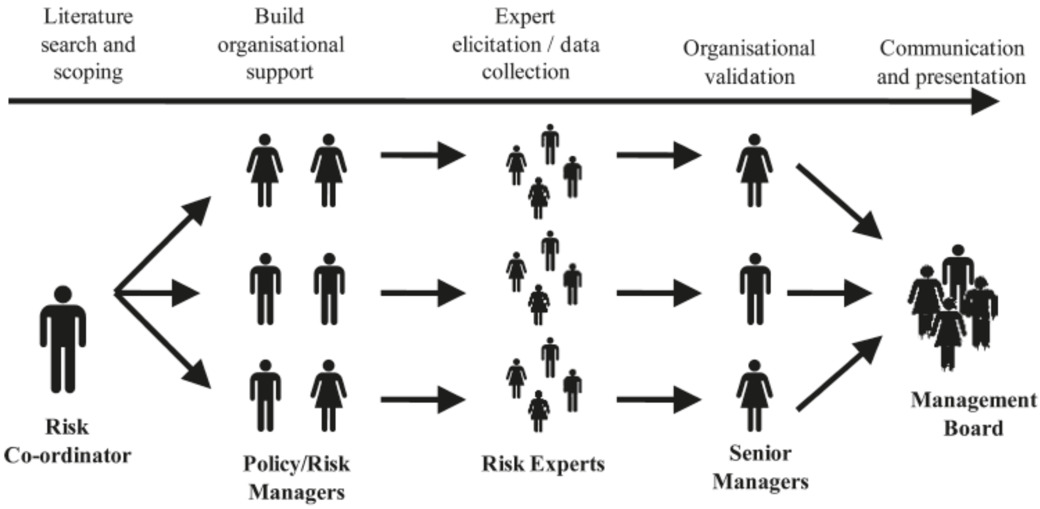


Figure 5-4 - Main actors and respective roles in the process (Prpich *et al.,* 2011)

Assembling the team commenced with a meeting with the Board in which the overall methodology was presented and the strategic/corporate objectives were identified (chapter 6.1). Acknowledging the strategic objectives allowed the appointing of the respective risk managers – the risk of not meeting those objectives (HM Treasury, 2004). A workshop was then held with the participation of the Board and of risk managers, so that the project was explained and discussed in broad terms. Then, a series of 14 meetings was carried out with each risk manager (heads of department)[3], individually, in order to present a first draft of the systemic model of the strategic risks that had been developed in the meantime (chapter 6.2) and to ask them (i) for their feed-back; (ii) to nominate the risk experts in their departments[4].

The team from EPAL appointed to participate in this research project is presented in Appendix A.

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[3] DGA (Asset Management), PCG (Planning and Control Management), DAF (Administrative and Financial Department), DRC (Customers Relations), DRH (Human Resources), DIR (Infrastructures Maintenance), DOP (Operations), LAB (Water Quality Control), LOG (Logistics), JUR (Legal compliance), DGO (Design and Works), DSO (Organizational Development), DSI (Information Systems) and SG (General Secretariat).

[4] The number of Risk Experts nominated by each Risk Manager ranged from one to three.

Engagement of the team was leveraged by the following factors:

- Top management (the Board) buy-in;
- The whole project was explained to all players, thus each of them understood the global picture and realized the importance of their own contribution;
- The whole team was invited to attend the workshop where the results were presented, discussed and validated – this allowed them to verify that their contributions had been incorporated and also to learn more about the risks they manage and their respective interdependencies with others' risks;
- A training session about futures science was offered to risk experts, which constituted an enriching opportunity to broaden their knowledge.

A deep engagement of the team was achieved, which is expressed in their contribution to the baseline risk assessment phase (construction of the systemic model based on a bottom-up approach, strategic risks' evaluation, validation) and also to the futures' phase (identification of the key-drivers' projections, cross-consistency analysis and validation).

6 DEVELOPMENT OF A HOLISTIC APPROACH LINKING RISKS AND FUTURES

6.1 Strategic risks identification

6.1.1 Methods

Strategic risks are the risks associated with the non-accomplishing of the strategic objectives, which, in turn, are a reflex of the decision-makers' values. As such, strategic risks identification is entwined not only with the company's vision and mission but also with the respective values, thus requiring the involvement of the top management of utilities. Keeney (1992) defines "objective" as a statement of something that one desires to achieve, characterized by a decision context, an object and a direction of preference, and points out that there are different types of objectives (Figure 6-1):

- means objectives – act as a means to achieve the fundamental objectives;
- fundamental objectives – characterize an essential reason for interest in the decision situation;
- strategic objectives – represent the decision makers' ultimate end objectives, providing common guidance to all decisions; strategic objectives do not vary from day to day, but rather should be stable over years.

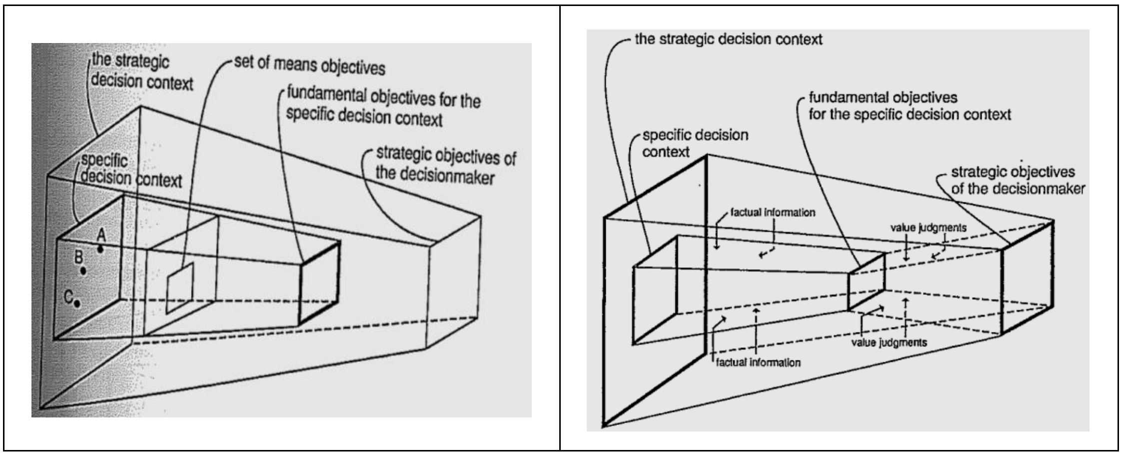

Figure 6-1 – The decision frame based on value-focused thinking: a) base framework; b) with indication of the flow of information (Keeney, 1992)

Although properly structuring strategic objectives represents a powerful opportunity for organizations, as it establishes a “sound basis for decision-making that can be repeatedly used”, providing a “stable reference point for even the most turbulent of decision situations” (Keeney, 1992), this potential has been disregarded by many companies, which define their strategic objectives through vague statements that everyone would agree with, thus providing minimal guidance and permitting taking ad-hoc decisions that will not make sense in the broader context of the organization (Keeney, 1992). Keeney (1992) advocates that one of the reasons for this to happen is the lack of existing guidance, and suggests the following approach in order to help identifying (steps i. to iii.) and structuring (steps iv. to v.) strategic objectives:

(i) to enlist a facilitator to guide the process;

(ii) the facilitator should have the decision context or some objectives roughly outlined prior to engaging in a discussion about the decision situation;

(iii) to elicit the strategic objectives from the decision-maker, following the principle that a specific decision context is part of a larger one, which, in turn, is part of a still larger one, until the strategic decision context is reached;

(iv) to identify the fundamental objectives associated with the strategic objectives, which must lie somewhere between the decision context (as they should be *controllable*) and the strategic objectives (as they should be *essential* for the accomplishment of the strategic objectives);

(v) to structure the fundamental objectives, by constructing either a hierarchy based on value judgements or a means-ends network based on causal judgments about facts, or a combination of both.

The steps concerning the structuring of strategic objectives will be recalled in chapter 6.2.1. In this research, strategic objectives were identified by the facilitator in a meeting with the chairman of the board, where the heads of the Planning and Management Control and the Asset Management departments also participated.

6.1.2 Results

The strategic objectives identified for EPAL are the following:

- To guarantee the economic and financial Sustainability of the business, in the long term.

  Failing to meet this objective will mainly affect the shareholder.

- To guarantee adequate levels of business Profitability, each year.

  Failing to meet this objective will mainly affect the customers and the shareholder.

- To supply water with adequate Quality, i.e., that it will not harm customers' health.

  Failing to meet this objective will mainly affect the customers.

- To supply water in adequate Quantity, i.e., meeting every customer's needs (regardless of the reliability of supply or the water quality).

  Failing to meet this objective will mainly affect the customers.

- To supply water with adequate Reliability, i.e., ensuring the continuity of the supply (regardless of the water quality or quantity).

  Failing to meet this objective will mainly affect the customers.

- To ensure the Trust from the customers as well as the Reputation among other national or international water utilities.

  Failing to meet this objective will mainly affect the shareholder.

6.2 Systemic analysis of strategic risks

6.2.1 Methods

6.2.1.1 Construction of a systemic model: the influence diagram

At strategic level, risk assessments should integrate the different risks as a whole, as well as capture the respective interdependencies (Schiller and Prpich, 2013; ISO 31000, 2009). Nevertheless, the way these principles may be operationalized is hardly known.

In this research, a systemic model of strategic risks was constructed, mainly based on two different, yet convergent and complementary, approaches. The first one consisted of identifying and trying to structure the fundamental objectives related to the strategic objectives – steps (iv) and (v) mentioned in 6.1.1. The second approach was to draw an event-exposure-harm diagram (Gormley *et al.*, 2011). Despite the fact that the former is focused on the objectives to be attained whilst the latter is focused on what can happen that poses a threat to the objectives, they both stem from the identification of causal relationships and can be combined to form a holistic model of strategic risks, as these are understood as the risk of not meeting the objectives. In fact, "harm" is related to the consequences of failing to meet each of the "fundamental objectives". The overall result is a cognitive map, also referred to as "influence diagram", which allows the identifying of the interdependencies between risks, because when mapping the exposures to the events it soon became clear that similar events led to different exposures which, in turn, may be associated with different harms to strategic risks.

Since strategic objectives are too broad for most decision situations, fundamental objectives help narrowing the decision context, permitting a better control over the consequences (Keeney, 1992). Therefore, identifying the fundamental objectives related to each of the strategic objectives becomes critical, and two ways may be followed in order to do it: (i) bottom-up - the means objectives are repeatedly questioned – e.g. "why is this objective important in the decision context?" – until the answer indicates direct implication on a strategic objective, thus letting the fundamental objectives emerge; or (ii) top-down - working back from the strategic objectives and challenging them to make fundamental objectives arise – e.g. "what are the immediate causes for meeting this strategic objective?" (Keeney, 1992; Waal and Ritchey, 2007). Usually, this is an iterative process, as it is often necessary to move back and forward until the fundamental objectives are stabilized (Keeney, 1992). Then, with both strategic and fundamental objectives well defined, Keeney (1992) advocates that constructing a means-ends objectives network is one of the possible ways to structure objectives, where “the lower-level objective is a means (that is, a causal factor) to the higher-level objective”. Although this process clearly resembles that of influence diagrams used in decision-analysis, a distinction between the two of them is that a means-ends objectives network may not include all the causal factors, as these may not be important within the decision context (Howard and Matheson, 1984 and Schachter, 1986 in Keeney, 1992). In this research, therefore, fundamental objectives were no further structured – instead, they were used to form the basis for a different approach: the events – exposures – harms model, where “harms” are associated with the consequences of failing to meet the fundamental objectives. Taking on this premise, events (definable root cause activities that pose a threat to the fundamental objectives) and correspondent exposures (resulting from a progressive challenge from a source of a hazard) were identified and mapped in an influence diagram – a cognitive map of cause-effect relationships between factors in the situation under debate (Warren, 1995), where the components or states are interconnected by directed graphs consisting of nodes and arrows (Kosko, 1986 in Amer *et al.*, 2013). Such diagram may be built by asking risk experts the following questions (Waal and Ritchey, 2007):

(i) What are the variables and variable values?
(ii) What does the graphical (e.g. causal) structure look like – i.e. between which variables are there dependencies and what are their causal directions?
(iii) What are the strengths of these dependencies, as depicted in the graphical structure?

The facilitator then compiles all the answers and combines them into one single diagram. This tool allows the capturing of diverse mental perspectives and presents them in an intuitive visual way that facilitates an understanding of interdependencies and promotes discussion among risk experts and managers (Waal and Ritchey, 2007; Amer *et al.*, 2013). One of the main advantages of this technique is that the final diagram does not represent the mental map of a single person but rather it reflects the mental map of the organization, incorporating all the contributions from the risk experts, thus backing their buy-in (Warren, 1995). However, building such a diagram may take considerable time, requiring adequate facilitation (Warren, 1995) and care should be taken so that the degree of detail of the influence diagram should not lead to too large and complex models (Warren, 1995; Amer *et al.*, 2013). Recently, the concept of "Fuzzy cognitive mapping" gained popularity (Aguilar, 1995 in Amer *et al.*, 2013) – it can be considered an extension of the traditional cognitive maps through the incorporation of weighted causal links, which may be useful when a certain state is influenced by an equal number of negative and positive ingoing arrows (Hans-Horst and Jetter, 2003 in Amer *et al.*, 2013).

Recent advice is that hazardous events – events that present very low likelihood but catastrophic consequences – should not be combined into the same analysis as others (US-NRC, 2010; Cox, 2012), given their peculiar characteristics:

- they may affect all strategic objectives;
- they are probable (usually low likelihood) but unpredictable (Cox, 2012; Renn, 2008b);
- their consequences are known to be "catastrophic", but these can be far more devastating that one can imagine (Vlek, 2013);
- there are no control barriers robust enough to prevent exposures to these events from occurring, thus the corresponding risk management strategies differ from the non-hazardous events' ones (Kleink and Renn, 2002) by mainly addressed contingency plans to assure business continuity (HM Treasury, 2004; Pollard et al., 2004).

In this approach, the solution found was to depict these events (earthquakes, tornados, flooding and terrorism) by vertical bars spanning all strategic risks, prior to the remaining events.

Barriers in place along each pathway (that is, existing mechanisms to control risks) were identified and characterized in terms of the respective effectiveness, as they may contribute to lowering the likelihood and consequences of risks; in fact, keeping those barriers robust is the essence of risk management (Carter, 2012). The influence diagram - with and without the control barriers – was intentionally fitted in one A4 sheet, to allow decision-makers to have a global picture of the pathways to risks. However, this did not allow the depicting of a full characterization of each of the components of the influence diagram, so a complementing database was created, registering all the relevant information associated with each event, exposure or harm.

6.2.1.2 Likelihood and consequences evaluation

Besides allowing a holistic comprehension of the strategic risks and their interdependencies, the systemic model was also intended to support the classification of the likelihood and consequences of strategic risks. For this purpose, semi-quantitative scales were employed, due to the multi-dimensional nature of risks, which make it difficult to use a quantitative approach (Altenbach, 1995; Andrews *et al.*, 2003; FAO/WHO, 2009).

A logarithmic scale was used to characterise the likelihood of identified events occurring in the following 18 months (starting in 2012). Assessing each of the events, exposures and harms' likelihood was based on the existing studies at EPAL as well as on empirical and expert knowledge (Wall and Ritchey, 2007), captured in semi-structured interviews with risk experts, and the result was made conditional on the outcome of earlier steps in the diagram (Wall and Ritchey, 2007; Gormley *et al.*, 2011) taking into consideration the efficacy of existing barriers, as well (Pollino and Hart, 2008).

The definition of the consequences' scale requires value judgments that are specific to the organization (Keeney, 1992; Renn, 2008a). Moreover, choosing a set of attributes that comprehensively describe hazards' impacts while keeping the list short enough to be cognitively tractable, i.e., to find the right compromise to balance totality and usability, constitutes a major challenge (Willis *et al.*, 2004; Pollard *et al.*, 2004; Prpich *et al.*, 2011). In this work, consequences were described by their type, extension (magnitude) and duration (including irreversibility) – "TED". Thresholds for the different classes of consequences were defined taking into account real possible situations (e.g.- for reliability of supply: what would be the worst case of a critical infrastructure failure? Could it be considered "catastrophic"?), as well as the reaction time – also known as "risk clockspeed window" (Caldwell, 2012). For example, the threshold of "six months" regarding the consequences of not having enough water at sources to supply, took into account the estimated time to implement new abstractions or transfers from other water sources or transport systems. Finally, it became necessary to find the best correspondence of each class' significance across all the consequence categories. In order to do so, two ways were analysed: (i) classifying all consequences on a Likert scale (Likert, 1932) of 1 to 5 and then ranking the relative (pairwise) importance of the objectives, assigning weights and recalculating the value of each class; or (ii) reflecting the relative significance of consequences on a matrix or risk "heat-map" and constructing a narrative for each strategic risk (Prpich *et al.*, 2013). Following practical examples of some "best in class" utilities (e.g. E.On), the second approach was adopted, since it makes it easier for the decision makers, risk experts and risk managers to understand it.

The scale for consequences evaluation was then applied to the harms associated with each strategic risk. The work done in EPAL confirmed that the order in which likelihood and consequence were assessed is not interchangeable (MacGillivray and Pollard, 2008): ranking order of impacts should be done first, so that potential major risks are not dismissed prematurely (Caldwell, 2012). Each of the classes of consequence for a given risk may be associated with its own class of likelihood, so every pair of consequence/likelihood was carefully analysed in order to determine what the final evaluation of the risk would be.

"Heat-maps" (map positioning risks in 2D schematics presenting likelihood and consequence scales on the vertical and horizontal axes) are a practical and intuitive way to support discussions with decision-makers, who "desire a structured and supportable basis for acting on the risks posed by a policy area over a given future" (Prpich *et al.*, 2013), as they condense a large body of evidence captured from experts and literature. Nevertheless, these should not be used in isolation, since the complexity of policy-level risk cannot be fully captured in the “heat-maps” (Prpich *et al.*, 2013). As such, each strategic risk was represented by an ellipse, indicating a central tendency and a span of uncertainty along the vertical and horizontal dimensions, and these were further characterized by a narrative on risk character, including existing control mechanisms.

Offering a systematic treatment of uncertainty in order to improve the management of uncertainty in decision making processes is neither simple nor consensual (Krayer von Krauss *et al.*, 2006; Patt, 2007; Pollard *et al.*, 2008). While the elliptic shape of risks in the “heat-map” reflect the aleatory uncertainty - through the size of the horizontal and vertical axes - epistemic and decision-making uncertainties are more difficult to characterise here. Nevertheless, and because it is important for a decision-maker to know how confident experts were when evaluating the likelihood of a given risk, in this research such type of uncertainty was recorded in the database, according to the following criteria:

- “Low” – there is empirical or scientific evidence;
- “Medium” – there is no empirical or scientific evidence, but there is a high level of agreement among experts;
- “High” – there is no empirical or scientific evidence and there is a low level of agreement among experts.

6.2.1.3 Semi-structured interviews and validation workshop

Delivering all of the above involved the risk facilitator, the risk experts and the risk managers.

Brainstorming is considered a useful method to collect a broad set of ideas (ISO 31000:2009). Building on the results of a previous brainstorming exercise at EPAL where risk experts and risk managers addressed the question “what do you consider to be the strategic risks of EPAL?”, the answers were reframed by the risk facilitator into the different categories related to the strategic objectives, allowing the drawing of a first sketch of pathways of threats to strategic objectives, incorporating events, exposures and harms. The barriers in place along each pathway - to lower the likelihood and consequences - were also pre-identified by the risk co-ordinator who, at a second stage, enriched the influence diagram with inputs from several studies related to one or more strategic risks that had been carried out in the company (Appendix B).

Face-to-face semi-structured interviews with individual or small groups (maximum three participants) of risk experts were conducted (n=12, c. two hours duration), usually in their offices. Following Robson's (2002) recommendations, sequenced questions included[5]: (i) an introduction by the researcher; (ii) main body of the interview, including how they addressed the draft influence diagram – "is that correct?"; "what could be added – why?"; "what should be removed – why?", (iii) closure – outlining the importance of their contribution. This procedure allowed the influence diagram to be progressively enhanced by adding (and, sometimes, removing) events, exposures and harms as well as the respective interactions and control barriers. Experts were also asked to comment on the definition of the consequences' scale and on the likelihood of the events, exposures and harms. Tape recording or handwriting the outcomes of the interviews in a notebook were considered two alternative options. Whilst the former assures the accuracy of the registers, it also may make the interviewees (risk experts) feel uncomfortable and unwilling to share everything they knew, which is exactly the opposite of what is intended – an interviewer should try and get interviewees to talk freely and openly (Robson, 2002). Therefore, and following a discussion with the head of the Human Resources department about this issue, the second option was chosen: answers and observations were recorded in a notebook during the interviews, and then incorporated in the above mentioned database. This allowed (i) the registering of the different inputs; (ii) the subsequent detecting of inconsistencies between different experts' views; (iii) the statistical analysis of the control barriers (e.g. which barrier is the most frequent?); and (iv) the automatic production of forms / individual records for each of the events,

[5] 'Warm up' questions to establish rapport were not necessary, since in this action research framework risk experts were colleagues well-known to the researcher.

exposures and harms of the diagram (n=65), using the “mail merge” tool of MS Word.

Validation of the influence diagrams and of the likelihood/consequences classification of the risks was made through the series of meetings with risk experts and, in a second stage, during a one-day workshop with risk managers as well. Although carrying out the semi-structured interviews in individual meetings with risk experts made it more difficult for the risk co-ordinator to keep the focus on the relevant items and to analyse the conclusions, these allowed risk experts to bring up items that had not been considered *a piori*, thus enriching the outputs of the meetings. Conversely, in the workshop an effort was made so that an open discussion about the conclusions drawn by the risk experts would not happen, in order to avoid the discussion coming to “ground zero” again, because unlike the meetings with the risk experts, the workshop constituted a “one-shot” opportunity. Therefore, triangulation of the results of the interviews was done prior to the workshop, and conflict solving was made by a “second-round” of selected interviews with risk experts (Warren, 1995). Nevertheless, final validation was achieved in the workshop. To avoid bias, five groups with 8 to 10 people were formed, integrating the relevant risk managers and experts from different departments related to each of the six strategic risks (“guaranteeing business sustainability” and “guaranteeing business profitability” were discussed in the same group). To support the discussion, all groups were given: (i) an A1 size plot of the influence diagram coloured according to the likelihood of events, exposures and harms; (ii) a set of individual records where all the information that supported a specific event, exposure or harm was registered. Discussion was facilitated by specialists from Cranfield University (one per group) and, besides reaching consensus about the influence diagram and the likelihood and consequences’ estimation, risk managers and experts focused their attention on carefully analysing the strength of the control barriers, answering the following questions:

- Have I missed any existing barriers? Where?
- How effective are these barriers at achieving strategic objectives?

- Which barrier(s) are most critical?
- Which barrier(s) are most vulnerable (irrespective of their effectiveness)?
- Should there be additional barriers in the system?

The method followed – having individual interviews first and then a workshop - has the advantage of promoting thinking from all the experts (Keeney, 1992; Warren, 1995), whereas engaging in a workshop directly would make it easier for some experts to anchor on the ideas presented by the first speakers, no matter how good the facilitation might be (Keeney, 1992).

6.2.1.4 Summary

Table 6-1 synthetizes the methodology employed to evaluate strategic risks in the present.

Table 6-1 - Actions to build systemic model of strategic risks

Step #	Action	Basis of the action
1	Identification of the events, exposures and harms associated with each of the strategic objectives (influence diagram).	Knowledge of the system; Existing studies[6]; Literature review.
2	Identification of the interconnections between the events, exposures and harms of different objectives (influence diagram).	Knowledge of the system; Existing studies; Literature review.
3	Pre-definition of the scales to assess the likelihood and consequences' magnitude.	Knowledge of the system; Literature review.
4	Meetings with the risk experts, in order to: • Discuss the influence diagram; • Discuss the likelihood and consequences' scales; • Evaluate the likelihood of each risk.	Expert knowledge.
5	Compilation of the information gathered during the meetings with the risk experts and identification of inconsistencies or gaps (Appendix E). Evaluation of the consequences associated with the strategic risks.	Information gathered in step 4.

[6] The existing studies are listed in Appendix B.

Step #	Action	Basis of the action
6	Workshop with risk managers and risk experts in order to[7]: • Validate the influence diagram; • Validate the likelihood and consequences evaluation; • Discuss the completeness and the robustness of the existing barriers.	Information gathered in the previous steps.
7	Elaboration of the final documents, including: • Narratives (one per risk); • Influence diagram (final version); • Risk "heat-map".	Outcome of the workshop.

Despite the methods employed already being known, the novelty here was to combine them in such a way that it allows the holistic assessment of strategic risks, linking operational to financial and other strategic goals; the identification of the respective interdependencies; the bottom-up, deep engagement of the risk experts and managers of the company; the unveiling of tacit knowledge; and the degree of validation achieved.

6.2.2 Results

The information gathered during the meetings with risk experts is presented in Appendix E. The materials handed-out during the validation workshop can be found in Appendix F, namely the influence diagram and the records that further detail the "boxes" in the influence diagram. This appendix also includes information about the arrangements made for the workshop (participants, venue, date, etc.). Figure 6-3 represents the influence diagram that resulted from all the inputs, discussion and validation with risk experts and risk managers - previous versions that were prepared and challenged to discussion are presented in Appendix C, being evident the evolution (both in appearance and content) of the influence diagram. Figure 6-4 shows the influence diagram with the existing barriers along the pathway. The other final outputs of the baseline risk assessment, namely narratives and the influence diagram's records, can be found in Appendix G.

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[7] The workshop also included a second part dedicated to "Futures Scenarios"

Likelihood logarithmic scale was defined in terms of “occurrence / no. years”, as shown in Table 6-2.

Table 6-2 – Likelihood classification

Likelihood classification	
Certain	1/1
High	1/10 – 1/1
Moderate	1/100 – 1/10
Low	1/1000 – 1/100
Very low	1/10000 – 1/1000

The definition of the consequences’ scale involved the need to “specifically refer” to EPAL’s water supply system (Table 6-3). Consequences ranged from *minor* to *catastrophic*, and assigning meaning to these classes in each of the strategic objectives was done by answering the question “what could be the worst possible case in this strategic risk? Is it catastrophic? What are the consequences in quantitative terms?”. The analysis that supported the answers to these questions is presented in Appendix D. Finally, an evaluation across all strategic objectives was made, in order to have the same significance between them. It was found that not all strategic objectives had the same importance, thus worst cases were not always “catastrophic”.

Table 6-3 – Consequences classification

	Quality	Reliability	Quantity	Sustainability	Profitability	Reputation
Catastrophic	**50 or more** customers will present **non-reversible health problems**, including the **possibility of death**	**2.0 million or more** customers **will not be supplied** at all during 4 days or more	**50% or more** of the daily average flow will not be supplied during **6 months or more**	The company **will not be able** to accomplish its mission in the **next 10 years**		
Very bad	**Less than 50** customers will present **non-reversible health problems**, including the **possibility of death OR more than 5000** customers will present **reversible health problems**	**0.1-2.0 million** customers **will not be supplied** at all **OR 2,0 million or more** customers **will be partially supplied** during 4 days or more	**50% or more** of the daily average flow will not be supplied during **1-6 months**	The company **will not be able** to accomplish its mission in the **next 20 years**	The company will be **in deficit**	**One breaking news OR more than one non breaking news** per year defaming the **quality of the water** supplied
Bad	**Less than 5000** and **more than 500** customers will present **reversible health problems**	**0.1 million or less** customers **will not be supplied** at all **OR 0.5-2.0 million** customers **will be partially supplied** during 4 days or more	**25%-50%** of the daily average flow will not be supplied during **6 months or more**	The company **will be able** to accomplish its mission in the **next 20 years** but will struggle with **high economic or financial constraints**	The company will **decrease its profits by more than 75%** up to 100%	**One breaking news OR more than one non breaking news** per year related to **3rd party or H&S injuries**
Moderate	**Less than 500** and **more than 50** customers will present **reversible health problems**	**0.1-0.5 million** customers **will be partially supplied** during 4 days or more	**25%-50%** of the daily average flow will not be supplied during **1-6 months**	The company **will be able** to accomplish its mission in the **next 20 years** with **moderate economic or financial constraints**	The company will d**ecrease its profits by more than 25% and less than 75%**	**One breaking news OR more than one non breaking news** per year defaming the **reliability** of the water supplied
Minor	**Less than 50** customers will present **reversible health problems**	**0.1 million or less** customers **will be partially supplied** during 4 days or more	**Less than 25%** of the daily average flow will not be supplied during **more than 1 month**	The company **will be able** to accomplish its mission in the **next 20 years** with **minor economic or financial constraints**	The company will **decrease its profits by less than 25%**	**One breaking news OR more than one non breaking news** per year defaming the **governance of the company**

When mapping the events, it became clear that many of them were subject to contributing factors that may alter the respective likelihood (Hokstad and Steiro, 2006; ISO 31000, 2009), namely: (i) inadequate data / information; (ii) legal non-compliance; (iii) lack of communication; (iv) poor human resources management; and (v) inadequate governance. Their likelihood of occurrence was assessed using the same scale presented in Table 6-2, and the results are shown in Figure 6-2.

RISK FACTOR	LIKELIHOOD	RATIONALE
Inadequate data / information	**High (1/10 – 1/1)**	• *Not enough accurate or available data* • *Difficult to extract information out of data*
Legal non-compliance	**Moderate (1/100 – 1/10)**	• *Compliance with laws* • *Lack of stability in laws*
Lack of communication	**Certain (1/1)**	• *Within departments* • *Between departments* • *Outside the company*
Poor HR Management	**Certain (1/1)**	• *Difficult knowledge transfer (more than 200/740 employees are aged 55+)* • *Difficult to capture talents*
Inadequate governance	**Moderate (1/100 – 1/10)**	• *Excessive and unstable rulemaking from government*

Figure 6-2 - Likelihood of risk factors

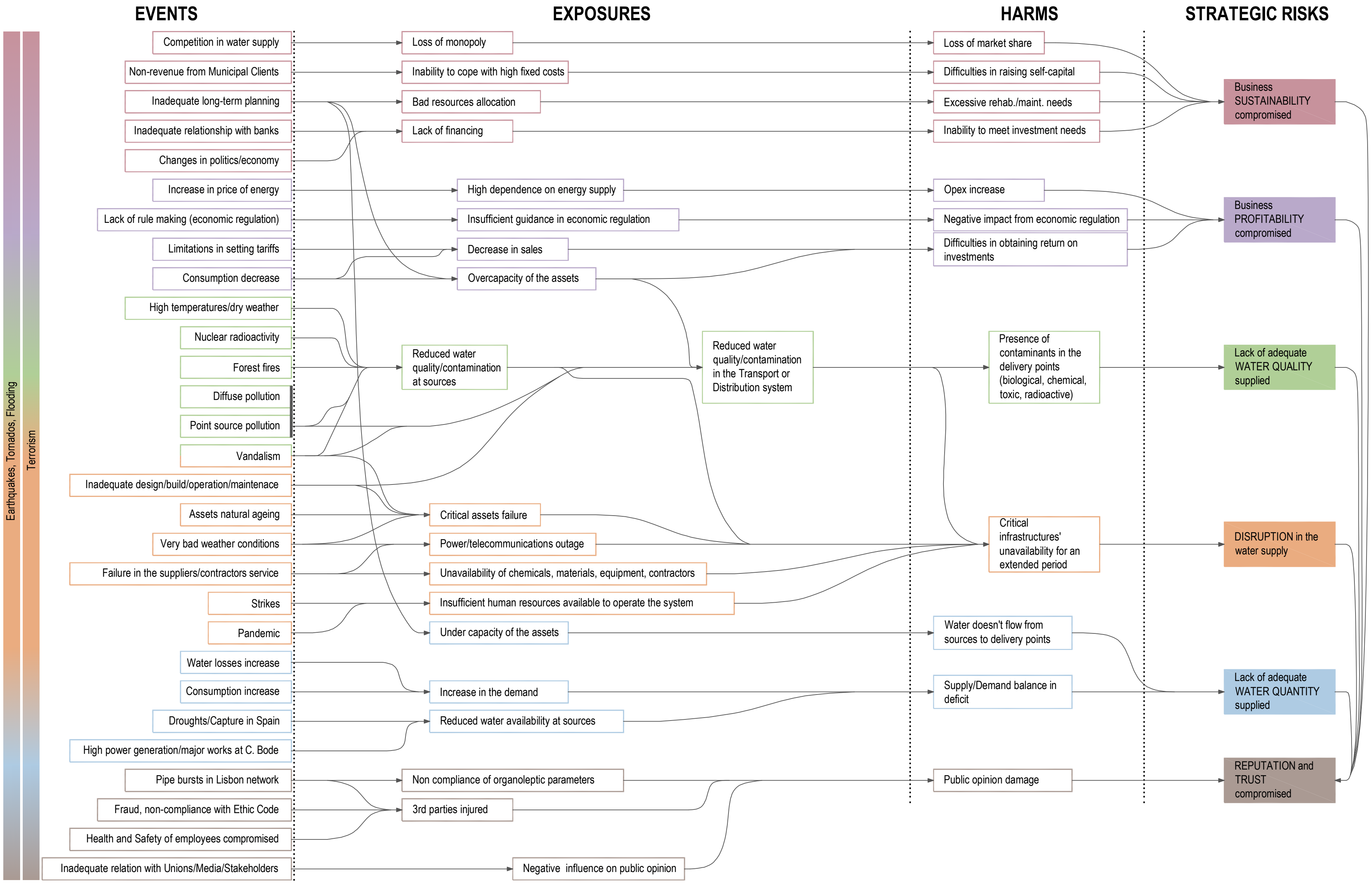

Figure 6-3 - Influence diagram of events, exposures and harms to strategic risks

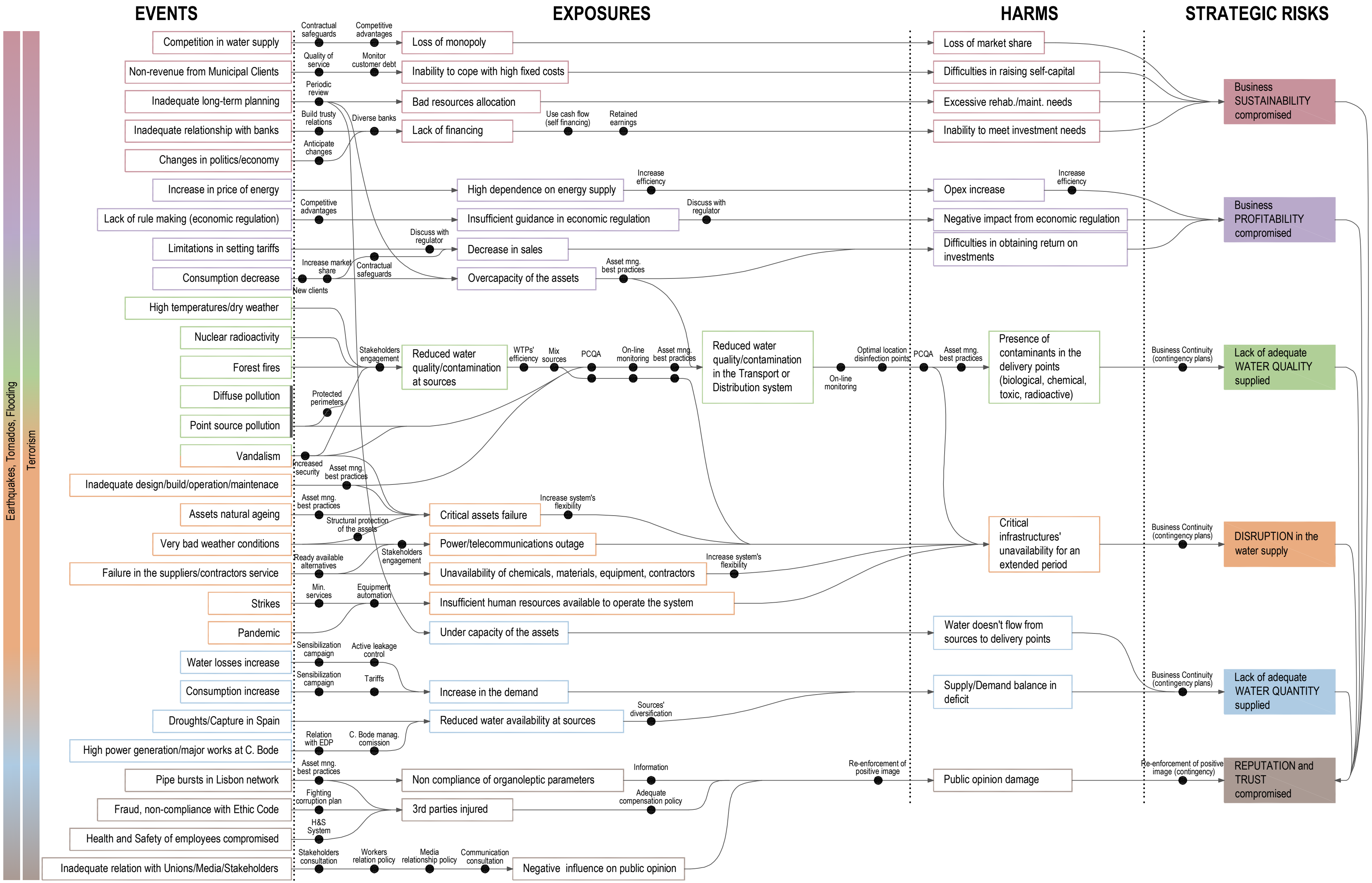

Figure 6-4 - Influence diagram of events, exposures and harms to strategic risks with barriers along the pathway

Figure 6-5 shows the influence diagram coloured according to likelihood of the events, exposures and harms, which allows (i) the identification of interactions between risks; (ii) the understanding of whether a risk has a naturally low likely of happening or if this is low due to existing barriers (see water quality *vs* water quantity); (iii) the showing of the existing barriers and their efficacy.

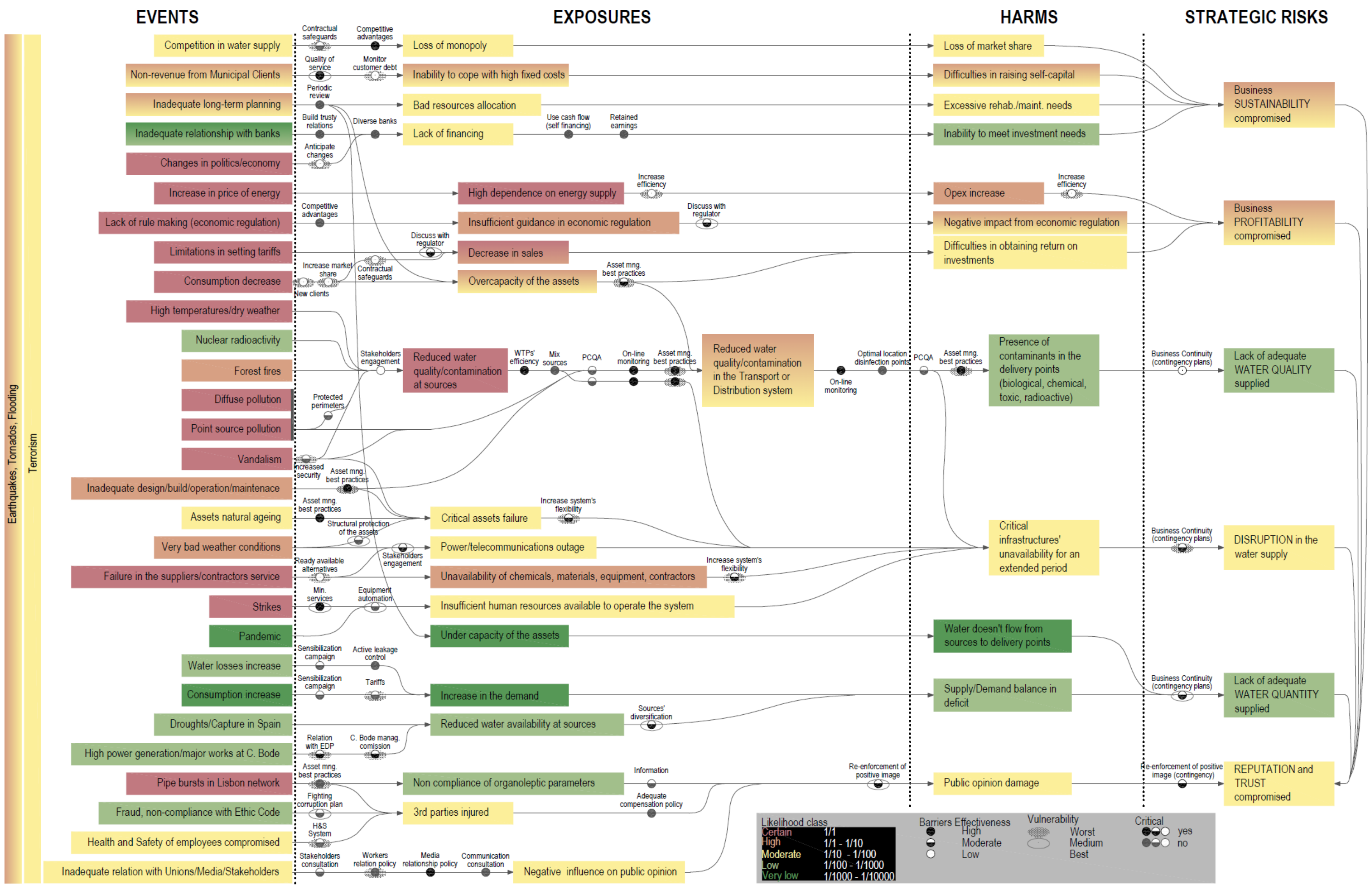

Figure 6-5 - Influence diagram for strategic risks at EPAL, coloured according to the likelihood of risks

The “heat-map” that resulted from likelihood and consequence assessments is presented in Figure 6-6.

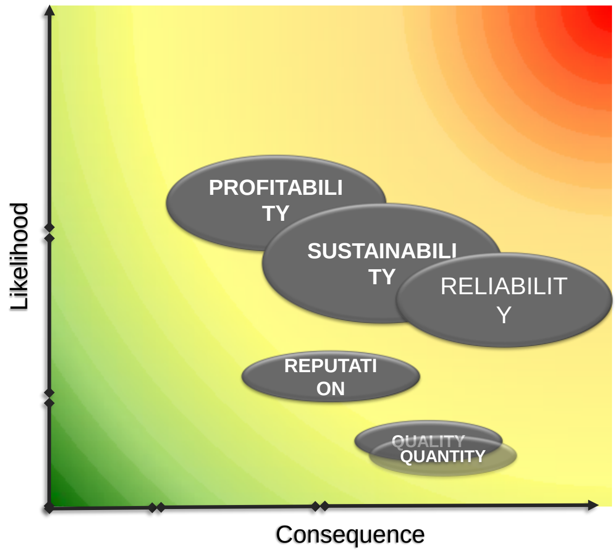

Figure 6-6 – “Heat-map” comparison with positioning of strategic risks

6.3 Futures and long-term strategic risk

6.3.1 Methods

6.3.1.1 “Given” mega-trends

Adaptaclima-EPAL is a three-year project promoted by EPAL, developed from October 2010 till November 2013, with the aims of (i) assessing the impacts of climate, demographic and land-use changes on EPAL's water supply system; and (ii) proposing adaptation measures to reduce EPAL's vulnerability. The global supervision of the project was committed to the present researcher, as Head of the Group for Climate Change study at EPAL. Scientific coordination was assured by Prof. Filipe Duarte Santos, from the Sciences Faculty of Lisbon University.

Climate change modelling focused on changes in precipitation as well as on maximum and minimum temperature until the end of the century, downscaled for EPAL’s region, using statistical downscaling techniques, from Global Circulation Model HadCM3 for IPCC scenarios A2 and B2. Data from European

Climate Assessment & Dataset with a regular grid of 25 x 25 km^2 was used to obtain observed data for these three variables within the study area, consisting of 52 points in the dataset. The downscaled model was duly calibrated and validated (Grosso *et al.*, 2012).

Demographic changes took on from the SRES and the Center for International Earth Science Information Network, CIESIN, scenarios for Portugal, which were then linear downscaled assuming the National Statistical Institute (Portuguese) data as starting points (Jacinto *et al.*, 2013).

Land-use changes took on SRES scenarios as well, regionalized for Europe and Portugal, and baseline data were obtained from Corine Land Cover 2000 survey (Jacinto *et al.*, 2013).

Thereby, the conclusions from the modelling of each of these three mega-trends (Jacinto *et al.*, 2013; Grosso *et al.*, 2012) were used in this PhD as "givens" - factors for which the possible future developments were assumed across all scenarios (CERF, 2012).

6.3.1.2 Future scenarios

Future scenarios were drawn for a 30-years horizon, using the morphological analysis, MA, since it is one that best fits a context that depends on a high number of uncertainties (Table 2-3), as is the case of water utilities. Using the four quadrants matrix method, for example, would have had the advantage of being very much simpler to model, but it would turn out to be inappropriate, because it could not capture the entire complexity associated with EPAL's context. Moreover, it has the disadvantage of requiring the researcher to choose two 'main' drivers to form the axis of uncertainty which, in effect, might not be the case in the future, when other drivers may become more important.

Morphological analysis is "a method for rigorously structuring and investigating the total set of relationships in inherently non-quantifiable socio-technical problem complexes", based on the identification of internal consistent relationships between states of parameters that describe the system (Ritchey, 2009). Its explicit use dates from the 18th century, but it was in the 1940s that the Swiss-born astrophysicist and aerospace scientist Fritz Zwicky, working in the California Institute of Technology (Caltech), developed a generalized form of morphological analysis which was employed in the USA and in Europe by a number of engineers, operational researchers and policy analysts for structuring complex engineering problems, developing scenarios and studying security policy options until the early 1990s (Ritchey, 2009; Ritchey, 2011). In 1995, Ritchey and his colleagues from the Swedish Defence Research Agency developed advanced computer software in order to reach the full potential of morphological analysis, namely allowing varying initial conditions, defining drivers and generating solutions or decision paths (Ritchey, 2009).

MA permits the overcoming of several methodological difficulties traditionally associated with modelling complex problems, namely (i) unlike quantitative techniques such as causal modelling or simulation, it enables the consideration of non-quantifiable and highly uncertain variables such as the ones associated with socio-political drivers; (ii) it makes it possible to audit or trace the process, even though it relies on judgmental processes; (iii) there are no formal constraints to mixing and comparing issues of a very different nature – instead, this is encouraged in order to fully characterize the problem (Ritchey, 2011). This happens because MA is a form of non-quantified modelling that relies on judgmental processes and internal consistency, rather than causality - though causality may be used as an aid to judgment (Ritchey, 2011).

The process begins with the identification of the key-drivers of change (Ritchey, 2011), bearing in mind the purpose of the scenarios' analysis, i.e. the focal question. In this research, the focal question was: "what are the plausible scenarios that provide a wide range of situations to test my risks against?". Taking into account the diversity of key-drivers that may shape the future, two approaches to help selecting the relevant ones are often followed: PESTLE (Politics, Economics, Society, Technology, Legislation and Environment) or STEEP-V (Society, Technology, Economics, Ecology, Political, Values) (Defra, 2008). Thereafter, each parameter should be assigned a range of relevant values or conditions (Ritchey, 2011), that is, the projections or “states” that each key-driver may assume.

In the present case-study, key-drivers were subject to a pre-selection by the researcher using the PESTLE approach, since “Legislation” and “Environment” are very important drivers for water utilities. Then, a one and a half day workshop took place (Appendix F), where experts from different areas in the company (n=23) and from Cranfield University (n=4) were gathered in three groups, each of which was moderated by specialists from Cranfield University, who guaranteed appropriate group dynamics (Johnson and Johnson, 2000). The role of the moderators was very important, because futures work naturally calls for broad representation and competing voices, and this heterogeneity always generates a certain amount of discord and misunderstanding (Defra, 2008). This is in line with what Ritchey (2009) advocates: MA should be carried out in small subject specialist groups of six to eight participants, excluding facilitators, and have the strong facilitation of practised morphologists. The workshop was shaped to address three main goals: (i) validation of the pre-identified key-drivers; (ii) characterization of the key-drivers; and (iii) identification of projections for each key-driver. After being introduced to the theme by specialists from Cranfield University, experts were asked to validate the pre-identified key-drivers. The corresponding characterization was then enhanced by the experts, who answered the following questions:

- “Summarise the main elements for the risks associated with international water utilities relevant to this key-driver.”
- “What are the dimensions to be considered for this key-driver?”

To guide the identification of projections for each key-driver, experts were asked the following question:

- “What are alternative plausible developments in the field of each key-driver?”

Experts were also asked to point out “wild-cards”, i.e., low probability, high impact events that were they to occur, would severely impact the human condition (Petersen, 2000). These are not mega-trends, but the awareness of the abrupt changes caused by them helps improving organisations' ability to adapt and function during those periods (Saritas and Smith, 2011). During the characterization of the key-drivers, comments from the experts were recorded on post-it notes and then stuck up on A1 sheets containing three key-drivers each. In a plenary session, facilitators presented the comments for each of "their" key-drivers to the whole group. As a whole group, experts discussed the items under each factor in turn, editing or adding comments, whenever required. The same procedure was adopted for the identification of the key-drivers' projections.

The results of the workshop enabled the construction of a "morphological box", by setting the parameters against each other in an n-dimensional matrix (Ritchey, 2011). The subsequent step in MA is the performance of a cross-consistency analysis, CCA, between each pair of projections: an iterative analysis-synthesis process to reduce the total set of formally possible configurations in the total problem space to a smaller set of internally consistent configurations, representing a "solution space", using Zwicky's principle of contradiction and reduction (Ritchey, 2011) which states that the pairs of conditions in the morphological box that are mutually incompatible should be excluded from the solution space. In this research, CCA - the pairwise comparison between every projection, where a judgment is made about whether that pair can co-exist, i.e., represent a consistent relationship – was executed by the researcher with the involvement of some of the risk experts, using CarmaTM software, which was made freely available by the Swedish Society of Morphological Analysis (Swemorph). According to Swemorph guidelines, each pair of projections was classified as "Good fit, or best fit, or optimal pair (-)"; "Possible, could work, but not optimal (K)"; and "Impossible or very bad idea (X)". These associations were then analysed-synthesized by the software, which enabled the detection of consistent relations (states that could happen at the same time) by "freezing" each of the projections under each key-driver and observing how the rest of the projections reacted. When the detected relations revealed to be coherent – corresponding to optimal or sub-optimal solutions –, then a set of consistent key-drivers' projections were identified, thus permitting the forming of a scenario.

The final step of MA for scenario building is the selection of scenarios, based on the results of the CCA (Ritchey, 2011). There are an infinite number of stories about the future, so the challenge is to focus on those stories that are important (Saritas and Nugroho, 2012). In this research, the selection of scenarios was guided by the focal question: "does this scenario provide a wide range of situations to test my risks against?", from where four configurations representing important situations (new possibilities or confirmations of earlier expected results) for the risk analysis context were chosen - literature review shows that creation of three to five future scenarios is appropriate for a scenario project (Amer *et al.*, 2013). In the end, a short narrative was written for each scenario.

6.3.1.3 Long-term risk assessment

Once the scenarios for the futures were established, current strategic risks were reviewed. To explore how these baseline risks would change under each of the selected scenarios, the first step consisted of verifying if the influence diagram would still be valid. Next, likelihood and consequences associated with each risk were reassessed considering the context associated with each scenario. Finally, for each scenario, a narrative of the evolution of baseline risks was also written, and the graphic visualization of the corresponding "heat-maps", side-by-side, was presented.

6.3.1.4 Summary

Table 6-4 synthetizes the methodology followed to evaluate how baseline strategic risks evolved under given future scenarios.

Table 6-4 - Steps involved in the re-assessment of baseline risks in the future

Step #	Action	Basis of the action
1	Literature review, learning and discussion with Principal Research Fellow on "building futures" (in Cranfield University).	Literature review; Lecture and discussion with Futures' Expert.
2	Pre-selection of the key-drivers. Identification of "givens".	Knowledge of the system and of existing studies; Discussion with Futures' Expert.
3	Workshop with Risk Experts in order to: • Validate the key-drivers; • Estimate the projections associated to each of the key-drivers.	Expert knowledge.
4	Compilation of the information gathered during the workshop.	Information gathered in step 3.
5	Analysis of consistencies between key-drivers, using proper software.	Information gathered in the previous steps; expert knowledge.
6	Construction of futures' scenarios and writing up narratives.	Results of the cross-consistency analysis.
7	Re-assessment of baseline risks under each future scenario	Re-evaluation of likelihood and consequence associated with each risk.
8	Comparison of strategic risks in the present and in the future	Side-by-side portraying of "heat-maps" in the present and in each future scenario.

Main tools and techniques applied were MA informed by expert elicitation. Similar to what was pointed out in 6.2.1.4, though these are not new, the novelty in this research consisted of applying them for the construction of future scenarios with a focal question centred on risk analysis – something that has never been done before.

6.3.2 Results

6.3.2.1 Key-drivers' Selection

Key-drivers selection was based on the PESTLE approach – Political, Economic, Social, Technological, Legal and Environmental.

The 12 drivers pre-selected by the researcher were:

- P – Organisational change
- ECO - Economic development/state of the economy
- ECO - Energy prices
- S - Population size / demographics**
- S - Consumption patterns and environmental behaviour
- T - Infrastructure development
- T - Technology development
- L – Regulation and legislation (EU and national)
- ENV - Climate change**
- ENV - Land use change**
- ENV - Water quality
- ENV - Water availability

Key-drivers marked with ** were considered to be "givens", resulting from the mega-trends analysed separately within the framework of Adaptaclima-EPAL. Conclusions of this project are that (i) no significant impacts are foreseen in terms of global demand for water as a result of socio-economic changes; (ii) in spite of the expected decrease of run-off to the main water sources, abstraction needs will still be available, except in periods of extreme droughts in Valada-Tejo and of consecutive years of extreme droughts in Castelo do Bode reservoir (the main water source); (iii) a precautionary protocol for the joint management of the reservoir shall be made between EPAL and EDP (the electricity company that uses the reservoir for hydro-power generation), to be followed especially in dry years; (iv) an increase of phosphorous loads is expected in Castelo do Bode reservoir, though it may not compromise the quality of treated water.

Following the respective validation at the workshop, two of these key-drivers were split into two, thus totalling 14, as is shown in Table 6-5. The splitting of "Organizational change" into two key-drivers, namely "External organizational change" and "Internal organizational change" is related to the characteristics of the current developments in the sector in Portugal, where merging and acquisitions between water companies are foreseen to occur in the short to mid-term. The splitting of "Legislation and regulation" into two key-drivers, namely "Environmental legislation" and "Economic regulation", was justified by the fact that the projections for each of these drivers are different in nature, and they might impact differently on the strategic decisions of the company.

Table 6-5 – Key-drivers selected

Key-driver	Description
External organizational change	EPAL's developing organizational arrangements with other companies in the sector.
Internal organizational change	EPAL's internal organizational re-arrangement.
Economic development/state of the economy	The size and future development of Portugal's economic output, expressed in terms of real Gross Domestic Product, average annual growth, and origin (expenditure approach).
Energy prices	The development in the cost of energy in all forms (gas, electricity, etc.) used in sourcing, treating and providing water resources.
Consumption patterns and environmental behaviour	The consumption decisions and lifestyles of individuals and their attitudes towards the environment.
Infrastructure development	The development of new infrastructure and how they deal with the issue of asset ageing.
Technology development	The potential opportunities and risks presented by technological development and its implications in the management of water delivery.
Environmental legislation (EU and national)	The characteristics of National and European laws, directives and agreements that drive and influence policies regulating water utilities. Such legislation defines the responsibilities within water utilities regarding the effects of water production to human health and ecosystems.
Economic Regulation	The way the Regulator may influence corporate strategy, in terms of Incentives to Quality of Service, Knowledge and Innovation.
Water quality	The changes in water composition and sediment associated with pollutant load.
Water quantity	The changes in average water flow available in catchments for use by water utilities.

6.3.2.2 Key-drivers' Projections and "Wildcards"

Projections for each key-driver (the alternative plausible developments in the field of each key-driver) discussed and selected during the workshop by the different risk experts are shown in Table 6-7.

The identified "wildcards" (low probability, high impact events) affecting EPAL are presented in Table 6-6. These are intended to complement the narratives, as they should be part of the testing of the actions to be put in place to minimize strategic risks under each scenario.

Table 6-6 – "Wildcards" identified for EPAL

Spain affects flow upstream.	Cheap de-salinization technology discovered.	Influenza pandemic affecting lots of workers.	Multi-utilities becomes a reality.
Loss of power supply	Finding new sources of ground water.	Climate change refugees, increasing water demand.	Supply chain lost (chemicals, equipment).
Aeroplane crash into dam or tower.	Act of terrorism or civil unrest.	Conflict between EPAL and EDP	Economic crisis bankrupts all external workforces making operations impossible.
Wild fires.	Land slide that ruptures dam.	Pipe burst along supply system	Fuel crisis due to conflict.
Workers' strike.	Disaster in Almaraz nuclear station.	China buys everything. Foreign capital interest.	Earthquake.
Tsunami.	Tornados affecting energy availability.	Salinization. Brine intrusion.	Accidental contamination of the reservoir.

Table 6-7 – Key-drivers' projections

External organizational change	Internal organizational change	Economic development /state of the economy	Energy prices	Consumption patterns and environmental behaviour	Infrastructure development	Technology development	Environmental legislation (EU and national)	Economic Regulation	Water quality	Water quantity
Status quo	Status quo	Growth	Significant increase	Consumption slight decrease	Resource scarcity: min. for Maintenance and min. for Capex	Low degree of automation; no global vision of system	Compliance driven by EU	Weak regulation - State	Significant improvement	C.Bode reservoir level>121,5 m or Tagus >+8m
Bulk merger	Cooperation	Stagnation	Slight increase or decrease	Consumption significant decrease	"Normal": Increase Maintenance and Decrease Capex	Developed degree of automation; global view of system	Compliance driven by National Law	Strong regulation - State	Slight improvement	C.Bode reservoir level>100m or +4m<Tagus <+6m
Verticalisation	Matrix management Department / Geography	Fluctuation	Remains the same	Consumption remains stable	Resource abundance: Decrease Mainten. and Increase Capex	Best in class. Imports / Develops and exports own tech.	Compliance driven by self-regulation	Strong regulation - Private	Remains the same	C.Bode reservoir level<100m or -1m<Tagus< +4m
Concession / Privatization		Recession	Fluctuation	Consumption slight increase			Compliance driven by lobby groups		Slight degradation	C.Bode reservoir level <89m or Tagus< -2m
Multi-utilities			Significant decrease	Consumption significant increase					Significant degradation	

6.3.2.3 Cross-consistency analysis

Carma^{TM} software, made available by the Swedish Society of Morphological Analysis for cross-consistency analysis to be performed in this research, allows the inclusion of a maximum of eight key-drivers. Therefore, the list of the selected 14 key-drivers for CCA had to be shortened, since even excluding the three "givens" from the analysis, there were 11 key-drivers remaining.

The "external" and "internal" organizational changes key-drivers were excluded from the analysis, because, ultimately, they may be considered as a state that will change in the near future rather than pervasively causing change, which, according to Saritas and Smith (2011), is the distinctive feature of trends. "Economic regulation" and "environmental legislation" were merged again, through the combination of the respective projections – this required the analysis of the pairwise comparison between each projection of each of these key-drivers with every other one of the remaining key-drivers, and observing which combination would lead to the same cross-consistency results.

Identified pairwise inconsistencies in the CCA (Figure 6-7) were mainly due to empirical constraints (high improbability or implausibility on empirical grounds), which is one of the three types of inconsistencies pointed out by Ritchey (2011) – the others are "logical contradictions" and "normative constraints". The results of CCA evidenced only one optimal configuration, which corresponds to the reference case (present situation), but other suboptimal solutions were found. Appendix H presents some comments regarding the assumptions made during the cross-consistency analysis.

		State of the e				Energy prices					Consumption pa					Water quality					Water availab				Regulation a				Infrastruct		
		Growth	Stagnation	Fluctuation	Recession	Significant increase	Slight increase or decrease	Remains the same	Fluctuation	Significant decrease	onsumption slight decrease	mption significant decrease	Consumption remains stable	Consumption slight increase	umption significant increase	Significant improvement	Slight improvement	Remains the same	Slight degradation	Significant degradation	evel>121,5m or Tagus >+8m	l>100m or +4m<Tagus<+6m	r -1m<Tagus<+4m	ir level <89m or Tagus< -2m	Compliance driven by EU	l economic regulation - state	r Weak economic regulation	economic regulation - private	tenance and min. for Capex	nance and Decrease Capex	ainten. and Increase Capex
Energy prices	Significant increase	-	k	k	k																										
	Slight increase or decrease	k	-	-	-																										
	Remains the same	k	k	k	k																										
	Fluctuation	k	k	k	k																										
	Significant decrease	k	x	x	x																										
Consumption patterns & environmental behaviour	Consumption slight decrease	k	-	-	K	-	-	K	-	K																					
	Consumption significant decrease	k	K	K	-	K	K	k	k	k																					
	Consumption remains stable	-	k	K	k	K	-	-	K	K																					
	Consumption slight increase	K	k	K	X	K	-	K	-	-																					
	Consumption significant increase	k	K	K	X	X	K	X	X	k																					
Water quality	Significant improvement	K	X	X	K	-	X	X	X	X	-	-	-	-	-																
	Slight improvement	-	K	-	-	K	-	K	-	K	-	-	-	-	-																
	Remains the same	X	-	K	X	K	-	-	K	k	-	-	-	-	-																
	Slight degradation	-	K	-	-	K	-	K	-	K	-	-	-	-	-																
	Significant degradation	K	X	X	K	X	X	X	X	-	-	-	-	-	-																
Water availability	C.Bode reservoir level>121,5m or Tagus >+8m	-	-	-	-	X	K	K	K	-	-	-	-	-	-	-	K	x	K	x											
	C.Bode reservoir level>100m or +4m<Tagus<+6m	-	-	-	-	-	-	-	-	-	-	-	-	-	-	K	K	-	K	K											
	C.Bode reservoir level<100m or -1m<Tagus<+4m	-	-	-	-	-	K	K	K	X	K	-	X	K	X	X	K	K	-	K											
	C.Bode reservoir level <89m or Tagus< -2m	-	-	-	-	-	X	X	K	X	X	-	X	X	X	X	X	X	K	-											
Regulation and legislation	Compliance driven by EU	-	k	k	x	-	k	k	k	x	-	-	-	-	-	-	-	K	X	X	k	k	K	k							
	Compliance driven by national law or Strong economic regulatio	k	-	k	k	k	-	-	k	x	-	k	k	-	x	K	-	-	K	X	k	-	K	K							
	Compliance driven by self-regulation or Weak economic regulati	k	k	-	k	k	k	k	-	x	k	k	-	k	k	X	K	K	-	K	k	k	-	-							
	Compliance driven by lobby groups or Strong economic regulati	x	k	k	-	k	k	k	k	-	k	-	k	k	k	X	X	X	K	-	-	k	-	-							
Infrastructure development	Resource scarcity: min. for Maintenance and min. for Capex	X	K	K	-	k	k	k	k	-	K	-	K	K	X	-	k	k	k	k	-	k	k	k	X	X	-	-			
	"Normal": Increase Maintenance and Decrease Capex	K	-	-	K	k	-	-	-	k	-	K	-	-	K	k	-	-	-	k	k	-	-	k	k	-	-	K			
	Resource abundance :Decrease Mainten. and Increase Capex	-	K	K	X	-	k	k	k	k	K	X	K	K	-	k	k	k	k	-	k	k	k	-	-	K	-	k			
Technology development	Low degree of automation; no global vision of system	K	K	K	-	x	k	k	k	-	k	-	k	k	x	-	k	k	k	x	k	k	k	-	X	X	K	-	-	X	-
	Developed degree of automation; global view of system	K	-	-	K	k	-	-	-	k	-	k	-	-	k	-	-	-	-	k	k	-	-	k	k	-	-	K	-	-	K
	Best in class. Import / Develops and exports own tech.	-	K	K	K	-	k	k	k	x	k	x	k	k	-	k	k	k	k	-	-	k	k	-	-	K	K	k	-	K	-

Figure 6-7 - Cross-consistency analysis

6.3.2.4 Selection of scenarios

The scenarios chosen are represented in Figure 6-8. The chosen scenarios meet what Bezold (2010 in Amer *et al.*, 2013) considers the most likely (expectable) – Reference scenario – , challenging (what could go wrong) – Water or Financial Scarcity – and visionary (surprisingly successful) – Strong Economic growth – possibilities, which also can be associated with Schwab *et al.* (2003 in Amer *et al.*, 2013) recommendations: to develop three scenarios – trend extrapolation, best-case and worst-case scenario.

State of the economy	Energy prices	Consumption patterns&environmental behaviour	Water quality	Water availability	Regulation and legislation	Infrastructure development	Technology development
Growth	Significant increase	Consumption slight decrease	Significant improvement	C.Bode reservoir level>121,5m or Tagus >+8m	Compliance driven by EU	Resource scarcity: min. for Maintenance and min. for Capex	Low degree of automation; no global vision of system
Stagnation	Slight increase or decrease	Consumption significant decrease	Slight improvement	C.Bode reservoir level>100m or +4m<Tagus<+6m	Compliance driven by National Law or Strong regulation - State	"Normal": Increase Maintenance and Decrease Capex	Developed degree of automation; global view of system
Fluctuation	Remains the same	Consumption remains stable	Remains the same	C.Bode reservoir level<100m or -1m<Tagus<+4m	Compliance driven by self-regulation or Weak regulation - State	Resource abundance: Decrease Mainten. and Increase Capex	Best in class. Import / Develops and exports own tech.
Recession	Fluctuation	Consumption slight increase	Slight degradation	C.Bode reservoir level <89m or Tagus< -2m	Compliance driven by lobby groups or Strong regulation - Private		
	Significant decrease	Consumption significant increase	Significant degradation				

Figure 6-8 – Selected scenarios: Scenario 0 (black) - Reference scenario; Scenario 1 (red) – Water scarcity; Scenario 2 (green) – Financial resources' scarcity; Scenario 3 (blue) – Strong economic growth

- *Reference scenario*

  As Portugal has just exited an economic recession, the state of the economy is becoming stagnant. Energy prices register slight positive or negative fluctuations, and consumption patterns evidence a slight decrease. Both water quality and water availability at source remain at good levels. Water supplied complies with national standards and economic regulation is becoming gradually stronger. Infrastructure developments return to their "normal" configuration, i.e., increasing maintenance and reducing capital investment, thus optimizing assets' life without compromising the agreed levels of service to the clients. The company maintains a developed degree of automation, allowing a global view of the system and its centralized operation.

- *Scenario 1 – Water scarcity*

  Downscaled climate change scenarios indicate that severe drought periods are expected to occur in the next 40 years. During these periods, that may extend over one year or more, there may be a fluctuation in the prices of energy, as energy production is also affected by droughts, as well as a fluctuation in the state of the economy. Consumptions will decrease due to restrictions imposed by EPAL and the regulator. Water quality at sources will also decrease, due to the reduction in flows in the water bodies, which augments the concentration of pollutants. This decrease of water quality may become significant if compliance with environmental standards is self-regulated and economic regulation is weak. In order to cope with the increased water treatment operational costs and the costs associated with the implementation of adaptation measures to water scarcity, along with the reduction in revenue due to a decrease in consumption, tariffs will be gradually increased. EPAL will decrease the regular investment costs, thus increasing maintenance expenditure, and will maintain a developed degree of automation, since having a global view of the system is shown to be crucial for its operation in this scenario.

- *Scenario 2 – Financial resources' scarcity*

  In a prolonged global economic recession context, water quality at sources gets worse, since industries and municipalities cannot afford adequate treatment of the wastewater they produce and, on the other hand, farmers tend to use non-approved pesticides. EPAL faces a significant decrease in consumption, which lowers annual revenue. Both capital and operational expenditures are constrained, and part of the installed automation system may begin to fail. EPAL moves from a preventive attitude in asset management towards a reactive one. Economic regulation is weak, since regulators know that water utilities have no financial resources either to put measures in place to accomplish the established levels of service or to pay any fines. Development of new solutions or technology may occur, due to the need to find cheaper ways to operate the water supply system.

- *Scenario 3 – Strong economic growth*

  Significant improvement in water quality happens in a context of strong economic growth. Although existing industries in the watershed increase their activity and new ones arise, they comply with EU water quality legislation and treat all the wastewater before it is discharged into the rivers or the sewage network. Farmers also use permitted pesticides only, complying with the Nitrates Directive. Municipalities' wastewater treatment is of secondary or tertiary levels. There is a slight increase in water consumption. This context of strong economic growth makes way to an increase in Capex, targeting trunk mains' rehabilitation because of their ageing process, and also enables the company to adopt or develop new technology, becoming "best in class". For example, EPAL augments its own power generation capacity, through the production of solar, wind and micro-hydric energy. As a result of all these factors, EPAL faces a reduction in Operational Expenditure, due to reduced costs with energy and chemicals, as well as to an increase in the revenue from the clients.

Since these scenarios were considered to be consistent stories of plausible and possible futures, the option of testing this approach with different software (due to the above mentioned limitations of the software that led the number of the key-drivers to be reduced from 14 to 11) was not considered.

6.3.2.5 Mid and Long-term Strategic Risks Assessment

Taking the influence diagram again as a basis, the likelihood and consequences of the strategic risks were reassessed for each scenario (except the Reference Scenario, which constitutes the base case). Changes occurred mainly due to alterations in the events' likelihood, as well as to the fact that some of the existing barriers along the pathway changed their robustness - criticality and vulnerability of some of the barriers also changed under the selected scenarios.

The results of these analyses are presented in Appendix I, as well as in Figure 6-9, Figure 6-10 and Figure 6-11. The main conclusions are as follows:

- Scenario 1 – Water scarcity

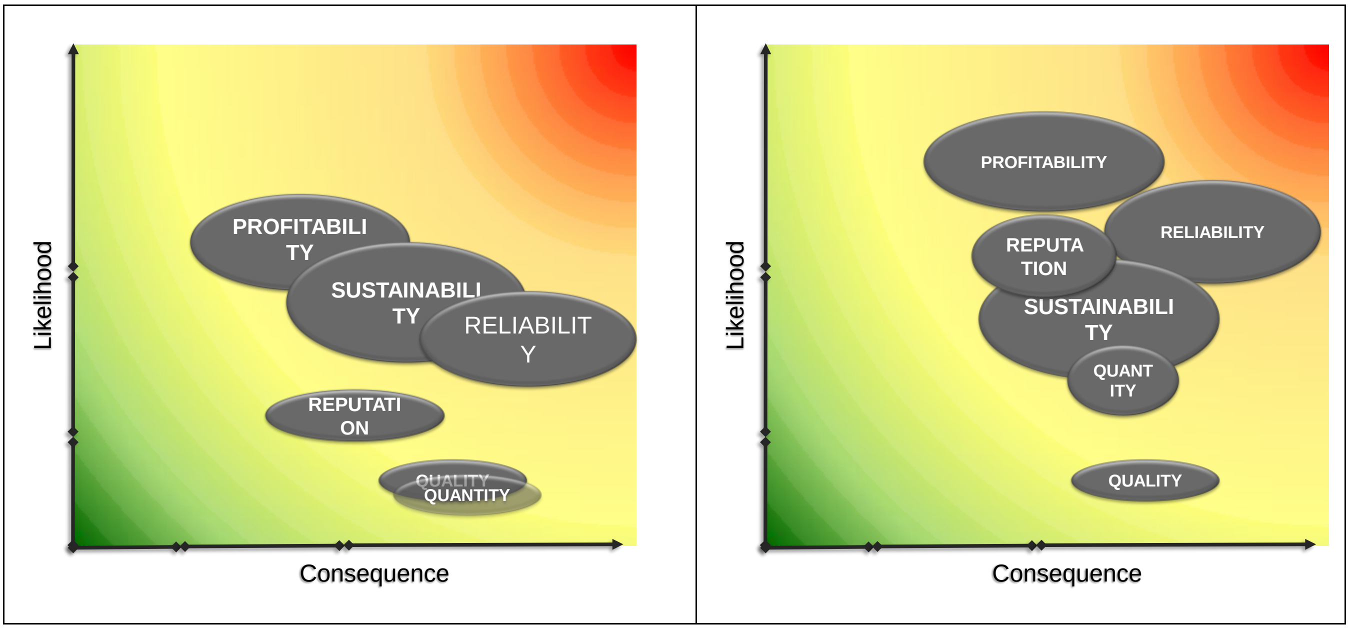

Figure 6-9 – Strategic risks: Reference scenario vs Scenario 1 – Water scarcity

Likelihood of not guaranteeing business sustainability remains "moderate to high", due to difficulties in raising self-capital. However, the likelihood of reducing market share becomes "low", since in a context of drought municipal clients' own water sources will become dry sooner than the ones managed by EPAL. Likelihood of business profitability being compromised increases from "moderate to high" to "high", mainly because of the rise in operational costs. The existing Water Treatment Plant, WTP, which presently accounts for c. 90% of the water production, should be able to cope with the potential degradation in water quality caused by more frequent and more intense forest fires in the surroundings of Castelo do Bode reservoir and by a higher concentration of pollutants. However, the other WTP and the chlorination points associated with the underground sources may not be able to deal with the expected decrease in water quality in the respective sources. Since supplying water with adequate quality remains a priority, there may be a temporary suspension of these water sources and, unless new interconnections between sub-systems or reinforcement of existing treatment are made, the reliability of local supplies may be affected. This is why, under this scenario, the likelihood of disruption in the supply increases to “moderate to high”. Nonetheless, the sense of responsibility and national cohesion in a context of extreme drought will lower the likelihood of strikes and, consequently, of having insufficient human resources available to operate the system. In terms of water quantity, Castelo do Bode reservoir will still have enough capacity to keep the overall supply/demand balance positive, providing there is a solid relation with the electricity company. However, local supplies associated with the Tagus river intake and with underground sources may be affected. Therefore, the likelihood of lacking adequate quantity supplied changes from low to moderate. Finally, the likelihood of reputation being affected will increase, as a result of the increased likelihood of “reliability of supply” and “water quantity”, even if they are caused by a natural phenomenon like extreme droughts. However, this risk may be turned into an opportunity if EPAL takes timely adaptation measures and communicates them.

- Scenario 2 – Financial resources' scarcity

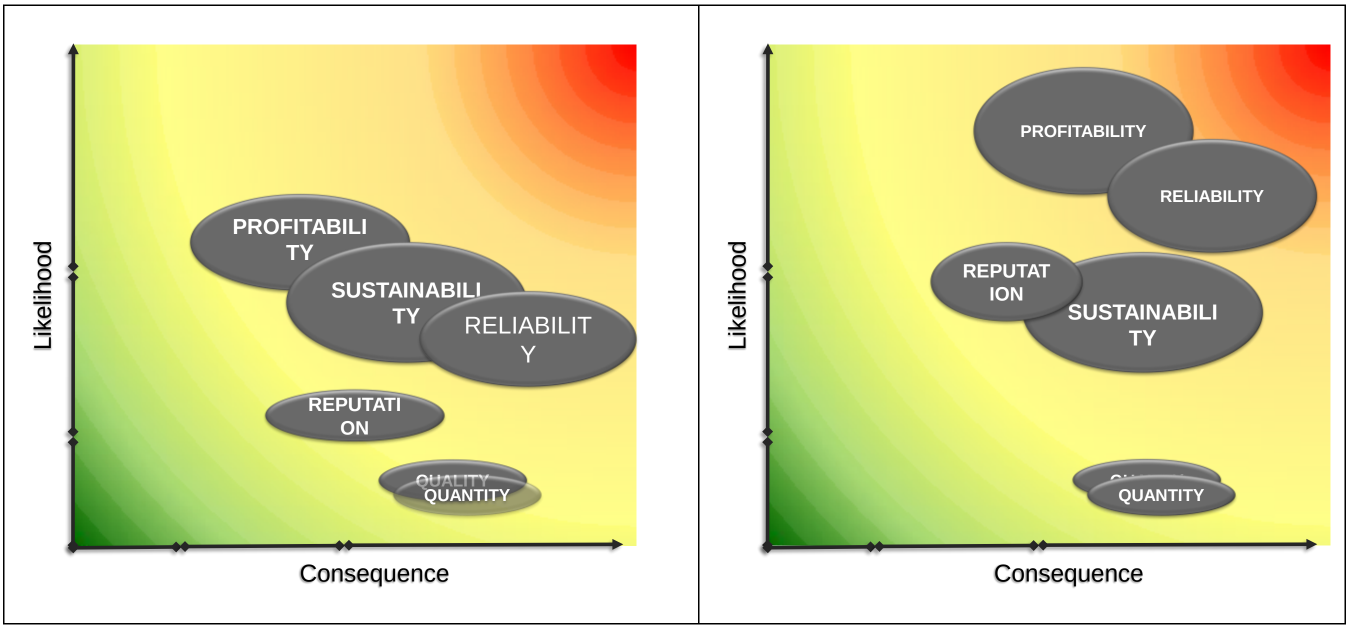

Figure 6-10 – Strategic risks: Reference Scenario vs Scenario 2 - Financial resources' scarcity

Due to recession, non-revenue from municipal clients starts happening more often, making it difficult for EPAL to cope with high fixed costs and thus, to raise self-capital. Investments may be delayed because economic situation jeopardizes international investors' confidence to finance EPAL. Business sustainability keeps its likelihood of being compromised as "moderate to high", due to EPAL's capacity of self-financing. Along with the non-revenue from direct and municipal clients, the significant decrease in the consumption leads business profitability to have a "high" likelihood of being compromised. Likelihood of disruption in water supply becomes "high", due to the lack of investment and to the change from a preventative to a reactive way of operating the system, which increases the likelihood of assets' failures. Moreover, recession also increases the frequency of strikes, which may lead to the unavailability of people to operate the system. There is a "moderate to high" likelihood that water losses increase, thus raising the water demand. Nonetheless, the supply/demand balance will still be positive. Reputation and trust have "moderate to high" likelihood to become compromised, because of the frequent disruptions in the supply.

- Scenario 3 – Strong economic growth

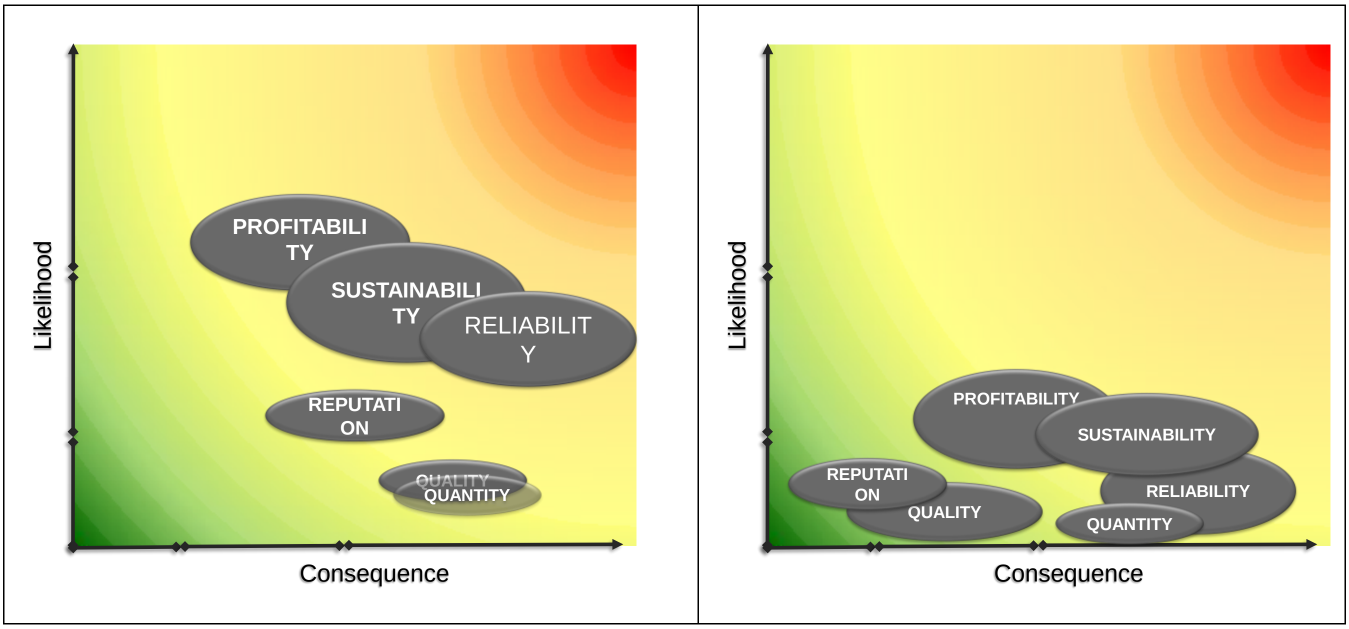

Figure 6-11 – Strategic risks: Reference Scenario vs Scenario 3 – Strong economic growth

In this scenario, the likelihood of not guaranteeing business sustainability lowers to "low to moderate", since it will become easy to raise self-capital as well as to meet investment and maintenance needs. As EPAL invests in producing its own energy, energy costs will decrease and, therefore, business profitability has a "low to moderate" likelihood of being compromised. Water quality at sources will improve, since people responsible for point source pollution will invest in adequate treatment facilities. EPAL will spend the necessary resources to rehab existing transport assets, as well as to reinforce on-line monitoring of water quality from source to delivery points, thus making it even safer than it is in the reference scenario. Along with the absence of major water quality problems, assets will become more reliable due to a focus on preventative management, and no strikes are expected to occur, since the company can reward the employees adequately. Therefore, likelihood of having a disruption in the supply becomes "low". Supply / demand balance remains positive. As for reputation and trust, the likelihood of compromising it is "low", although there may be "low to moderate" likelihood that public opinion is damaged, depending on the way EPAL manages its profits.

7 DISCUSSION

7.1 Introduction

This chapter discusses the results presented in the previous chapter in relation to prior art and seeks to offer claims for the novelty and significance of the research presented in this thesis. This research provides a systemic analysis of operational, programme-level and corporate risk for water utilities. It adopts a bottom-up, expert led analysis, capturing risk interdependencies across utilities - addressing aspects as diverse as people, skills and succession planning, the reliability of the asset base, human resources policies and governance structures. Such analysis represents the basis for long-term, strategic planning using future scenarios, built on changing economic, demographic, consumer behaviours, land-use, climate, technologic, legal, regulatory and asset management conditions.

Consequently, research insights addressed include those relating to interconnecting operational, tactical and strategic risk; influence diagrams as a systemic model for strategic risks; risk "heat-maps" as a basis for discussions with a Board; representing uncertainty; the development of future scenarios to represent the evolving character of strategic risks; the deliberative approach, enhancing organizational risk culture and avoiding bias; and potential generalization for other utilities.

These insights will guide the discussion on how the approach adopted addressed and overcame the limitations reported in literature about the implementation of enterprise risk assessments, namely: (i) the challenge of dealing with a high number of risk dimensions, requiring multi-disciplinary knowledge; (ii) the difficulty of capturing risks interconnections; (iii) the need to establish cross-departmental communication, which may represent a big effort for large utilities; (iv) the high degrees of uncertainty involved, due to spatial and temporal variability and (v) the need to account for long-term risks. Taking into account these limitations and, on the other hand, the fact that having in place robust ERM processes is deemed critical for utilities to manage risk proactively, ensuring the delivery of safe, reliable, wholesome and affordable drinking water whilst guaranteeing business sustainability, the central research question addressed in this thesis was formulated as:

How can a holistic approach linking strategic risks assessment and future scenario planning in water utilities be set up?

Answering this question embodies contributions to knowledge, which will be further explored in the next chapters. In order to enable a better understanding of where these contributions fit in the context of risk analysis, it is worth recapping the development of this field, particularly in what concerns comparative risk assessments.

Looking back at the evolution of comparative risk assessments, these emerged as a formal tool in the USA in the late 1980s, where USEPA played an important role in developing risk rankings based on numerical scores using a common quantifiable or monetisable measure of consequences. This first generation of comparative risk analysis carried out by the US Environmental Protection Agency (USEPA) in 1987 (USEPA, 1987) and the application of its techniques to a plethora of different policy problems, raised awareness of some shortcomings, namely the use of spurious precision in comparative risk rankings and the call for normative approaches when they were rarely applied in practice (Andrews *et al*., 2004). The New Jersey Comparative Risk Project (NJDEP, 2003) represented a landmark, because after considerable analysis and interrogation of data by multiple expert panels, the conclusion was that the analytical ‘constructed aggregation’ methodology adopted threw little light on the multiplicity of these risks (Andrews *et al.*, 2004). Further conclusions were that a ranked list of priorities has only limited value when the science is not in place to support such a list, and also that, for future exercises, emphasis should be on gathering evidence. This led to an evolution to the second generation of comparative risks assessments’ tools, which emphasized the need to understand the nature of risks, categorizing them and describing the respective dimensions of harm with attributes.

In parallel, the idea that a broader range of stakeholders should be involved in strategic decisions on environmental risk came to the forefront of the agenda during the 2000s, first in the USA (Fischer, 2000), and a few years later in the UK. The companion papers produced by Florig *et al.* (2001) and Morgan *et al.* (2001) discuss the value of deliberation itself within a group. However, within the context of environmental risk ranking, the difficulty of characterizing and representing the multiplicity of environmental harm for stakeholder input was noted (Willis *et al.*, 2004), especially at the strategic level, due to the extent of information and time needed to engage others in those diffuse, long-term strategic risk issues. Considerable research was undertaken by the Environment Agency of England and Wales to support its reporting to Ministers on the state of the environment (Pollard *et al.*, 2004), revealing a number of barriers to implementation, mainly related to a suite of communication shortcomings (Prpich *et al.*, 2011). Meanwhile, despite several important references about the notion of the social perception of risks had been acknowledged since the late 80s (Slovic, 1987; Kasperson *et al*. 1988), this concept gained popularity in the mid-2000s (Kasperson *et al.*, 2003; Renn, 2008a; Renn, 2008b), perhaps because the character of environmental harms allied to the inclusion of stakeholders' participation in risk assessments claimed a values' judgment behind the consequences scoring. Renn (2008b) called attention to the social construct of risks, besides its technical nature, and the dangers of amplification of risks. Also, the process of collating and synthesising the multiple dimensions of environmental harm was seen as needing to improve, as until then, the schematics in the work on harm characterisation (Environment Agency, 2002) were difficult to interpret.

In response, the emergence of third generation SRA tools occurred in the 2010s, seeking a methodological compromise to balance totality and usability in the attributes' selection, providing a more realistic approach about what can be achieved as well as concentrating on the communication and visualization of strategic risks with a principal objective of stimulating rich discussions on risk rather than delivering a 'top ten' of residual risks to address (Prpich *et al.*, 2011). The policy level framework intended to support strategic decision processes concerning environmental risks within the Department for Environment, Food and Rural Affairs (Defra) constitutes a good example of these third generation tools.

Despite the journey from the first to the third generation of SRA tools, the need to move to a more integrated approach between environmental, regulatory and financial risks has been noticed. In the water sector, global water governance emerged in the late 90s as a concept whereby water utilities are part of a wider system including the system's river basin, thus calling for the need to share the physical, regulatory and reputational risks with other stakeholders and agents outside the company (Morrison and Gleick, 2004). At the enterprise level, frameworks like COSO (2004), for corporate risk management have been developed and disseminated, though often based on risk rankings. Despite the denomination of COSO (2004) as an Enterprise Risk Management – Integrated Framework, the "integration" still misses capturing the interconnections between risks and the long-term perspective of strategic risks.

Looking back at the growing research agenda that has developed around comparative risk assessments at strategic level (Figure 7-1), one that straddles the engineering, decision and social sciences, we can affirm that this thesis (i) builds on prior art, by grounding on the character of harms, addressing communication between different levels of the organization in a participatory fashion and presenting the results through visual schematics; and (ii) represents a step forward in the field, by holistically assessing environmental, business and reputational risks, capturing their interconnections and cutting across operational, tactical and strategic levels; and by extending the assessment of risks to the long-term, through the novel linkage between the risk and the futures' sciences.

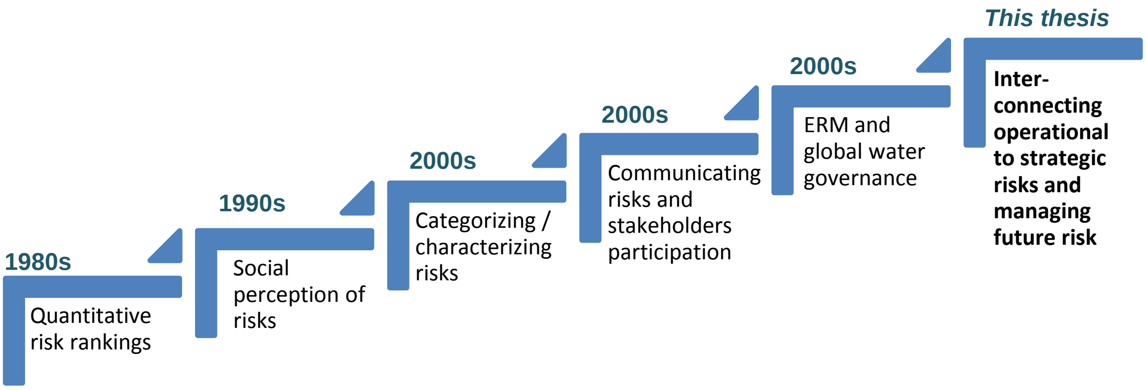

Figure 7-1 – Evolution of SRA frameworks for water utilities

7.2 Connecting operational, tactical and strategic risk

Relationships between operational, tactical and strategic risk tend to be disjointed and the interfaces between these risk types poorly informed (Strategy Unit, 2002). On the one hand, many of the existing risk based approaches are developed only at tactical (e.g. asset management (Wijnia and Herder, 2009)) and operational levels (e.g. water safety plans), not reaching the strategic level at all. Conversely, many strategic risk assessments are provided by external advisors who elicit strategic risk appraisals from internal audiences, resulting in cursory analyses or siloed assessments coordinated by the external party alone in isolation from deep organisational knowledge (Schiller and Prpich, 2013).

In this thesis, we methodically employed a “top-down” / “bottom-up” approach to assess corporate risks. The novelty of this approach is clear, because though the need to interconnect risk management at the three different levels has been widely acknowledged in literature (Pollard *et al.*, 2004), references to “how” this can be achieved are scarce. This thesis provides a methodology and illustration of how this can be achieved.

The “top-down” process initiated with the identification of the strategic objectives of the company in the hearth of this case study (chapter 6.1). The contribution and novelty embedded in this step are best described with regard to risk management frameworks which adopt an organization-wide focus. For example, the prominent COSO framework (COSO, 2004) states that “many organizations start by obtaining a top-down view of the most important risk exposures from key executives across the organization. This is typically accomplished by starting with a discussion of the organization's business strategy and its components and then identifying the principal risks that would impede its ability to achieve its strategic objectives. An alternative is to discuss the strategies and risks of each of its major business units. To aid in these discussions, some organizations prepare a list of major risk categories, such as operational, financial, legal, market and then discuss exposures to that risk category for the business overall or each significant business unit" (Frigo and Anderson, 2011). Despite the apparent practical tone of this guidance, a gap exists concerning what is meant by "strategic objectives". This is an important issue, because, on the one hand, all the subsequent risk analysis depends on the identification of these objectives and, on the other hand, the semantics of "strategic" gives way to very different interpretations, such as "critical for the business mission" or "critical for accomplishing the strategies in place", even though "strategic risks" and "risks to the strategy" do not have the same meaning. We believe this is one of the root causes for many enterprise risk assessments to miss the strategic focus of the organization, leading to underlying commensuration problems and to an indiscriminate inclusion of risks, including secondary ones, in the portfolio (Schiller and Prpich, 2013). Similarly to Frigo and Anderson (2011), in this research we considered strategic risks as those associated with impeding an organization to achieve its strategic objectives (chapter 6.1.1). However, drawing on literature from decision theory, we further detailed the meaning of a 'strategic objective' – "*the decision makers' ultimate end objectives, which should be stable over years, providing common guidance to all decisions"*, and distinguished it from a 'fundamental objective' - *an essential reason for interest in the decision situation*, and from 'means objective' - *a means to achieve the fundamental objectives* (Figure 6-1).

After the establishment of the corporate objectives by the Board of EPAL, the "top-down" process progressed with the identification and structuring of the fundamental objectives related to the strategic objectives, working back from the strategic objectives and challenging them to make fundamental objectives arise: “what are the immediate causes for guaranteeing this strategic objective?” (Keeney, 1992; Waal and Ritchey, 2007). We then combined the methods for structuring objectives with that of constructing influence diagrams in order to develop a systemic model incorporating the events, exposures and harms to those strategic objectives (Figure 6-3), where “harms” are associated with the consequences of failing to meet the fundamental objectives. The novelty here is found in the combined use of those methods. This research demonstrates that despite the fact that identifying and structuring objectives is focused on the objectives to be attained whilst the influence diagram is focused on what can happen that poses a threat to the objectives, both methods stem from the identification of causal relationships and can be combined to form a holistic model of strategic risks, as these are understood as the risk of not meeting the objectives.

Building the systemic model was an iterative process, moving back and forward until it was stabilized (Appendix C). This process was primarily informed by risk experts and risk managers, through brainstorming, semi-structured interviews and a validation workshop (Table 6-1), and it represents the point where we moved down from a strategic to an operational level of analysis. In fact, the systemic model was subsequently complemented with the identification of the existing control barriers along the pathways from the events to harms (Figure 6-4) and, furthermore, with the characterization of the respective effectiveness, criticality and vulnerability (Figure 6-5 and Appendix G). To our knowledge, no such approach has been implemented before. By exploring the development of a holistic model for strategic risk assessments in water utilities, we discovered a way to link operational to strategic risks, which, as mentioned before, usually are either appraised separately, by different teams and as if they pertained to two distinct realities within the company, or appraised all at the same level, in a miscellaneous assessment within an ERM framework, for example.

The process then moved up to a strategic level again, through the evaluation of likelihood and consequence of the risks. While the analysis of the likelihood associated with the events, exposures and harms was based on existing studies and on operational knowledge of the system (including the effectiveness of the existing barriers and the results of risk analyses held for specific business functions), the consequence scale (Table 6-3) reflected the strategic character of the risk assessment. Two main insights arise from this observation. Firstly, the consequence scale constitutes a critical issue in the linkage between strategic and operational levels, because “harms” may happen several times without affecting strategic risks at all. For example, pipe bursts happen every week in the city of Lisbon, but that does not compromise the objective “reliability of supply” from a strategic point of view – where consequences are expected to be much higher. Therefore, when assessing the likelihood of events, exposures and harms, risk experts were asked to keep in mind they were referring to events that have a given magnitude of consequences. Secondly, we turn to the controversial issue raised by MacGillivray and Pollard (2008), regarding whether risk analysis should be viewed as an over-arching discipline, normalised across the organization to fit a common format as advocated by the ERM concept, or, instead, it should be function-specific, fit for purpose. In light of that mentioned above, we argue the approach here represents a high-level, overarching risk analysis methodology, in the sense that it spans across all corporate objectives. However, it does not claim to replace the function-specific approaches (e.g. engineering; drinking water quality management; asset management; emergency management; occupational health and safety; financial analysis) that should be held at operational or tactical levels, but rather to bring the respective outcomes to a higher, strategic level of analysis. Critically however, this research illustrates how it is possible to assemble a systemic analysis from the business functions of a utility to inform a strategic analysis of risk (Figure 6-5 and Appendix G); and then project these forward in time (Appendix I).

Figure 7-2 illustrates the steps comprising the “top-down” / “bottom-up” process described above. Implementing this process, engaging both the Board and risk experts, building the systemic model with identification and characterization of the existing barriers along the pathway and developing an appropriate scale of consequences for the strategic level to guide the risk assessment, can be considered key to addressing the challenge of connecting strategic with tactical and operational levels of risk management. The contribution of the approach employed in this assessment to knowledge is significant, as it demonstrates how a 'golden thread' connecting operational and strategic risk in organisations may be achieved (Figure 7-2). Furthermore, this process improves communication between experts, managers and the Board and contributes to the pervasiveness of a risk management culture, which are crucial factors in implementing risk management in organizations (MacGillivray and Pollard, 2008; Summerill *et al.*, 2010; Allan *et al.*, 2013).

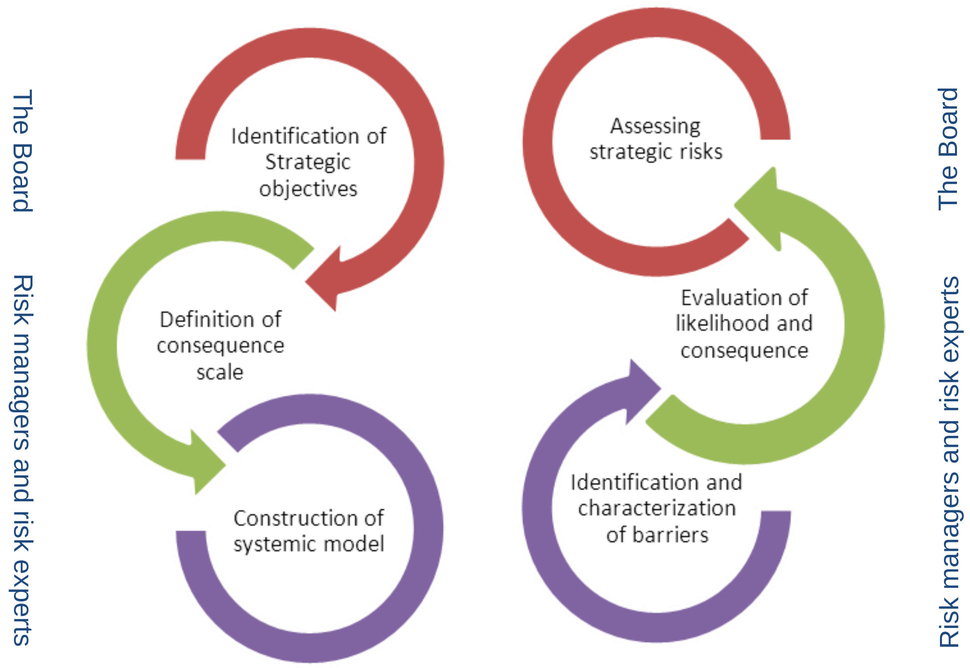

Figure 7-2 – The "top-down" / "bottom-up" approach interconnecting operational and strategic risks

7.3 Influence diagram as a systemic model of strategic risks

Strategic risks identified in this case study consist of compromising the economic and financial sustainability of the business, compromising adequate levels of business profitability, supplying water with inadequate quality, quantity or reliability, and compromising the trust from the customers as well as the reputation among other national or international water utilities (chapter 6.1.2). These are in line with the financial, regulatory, physical and reputational water risks drawn from Orr *et al.* (2011), Pegram (2010) and Levinson *et al.* (2008).

At strategic level, risks are best assessed across a whole system, rather than separately in siloes, with their interactions ignored (International Standards Organisation, 2009). However, strategic risks have been appraised in isolation, leading to a growing recognition of the need to integrate and harmonize these analyses (Means *et al*., 2010; Hamilton *et al.*, 2006; Renn, 2008b; Larson *et al.*, 2009; ISO 31000, 2009; Prpich *et al*., 2011). Attempts to relate physical or environmental risks like water quality, supply and resource have existed for over a decade (Bouwer, 2000; Hamilton *et al.*, 2006; Pollard *et al.*, 2004; Powers *et al.*, 2012), but a step change is still required to further integrate physical water risks with regulatory, financial and reputational risks (Frigo and Anderson, 2012). Despite the limited scientific literature on these water risks as a corporate concept (Schiller and Prpich, 2013; Pegram *et al.*, 2009; Orr *et al.*, 2011), the ERM concept is gaining popularity (Hoffman, 2008; Schiller and Prpich, 2013), even though its practical implementation presents some weaknesses, particularly as it does not take into account that most risks are interdependent (Beasley and Frigo, 2007 in Schiller and Prpich, 2013; Caldwell, 2012). Schiller and Prpich (2013) suggest the depth of advocacy required to fully achieve integrated enterprise risk management has not emerged.

Again, we observe that existing literature states there are interdependencies among corporate risks and that these should be taken into account in risk assessments, but a gap exists regarding "how" it can be done. Recent developments in the COSO framework already point out that "understanding risk interactions and then managing them requires breaking down silos" (Curtis and Carey, 2012). These authors suggest that "a simple way to consider risk interactions is to group related risks into a broad risk area (…) and then (…) three explicit ways to capture risk interactions (…) are risk interaction maps, correlation matrices, and bow-tie diagrams". When applied to a broad risk area, typically in the field of engineering, these methods are effective ways to capture interactions between events, allowing the implementation of detailed probabilistic (quantitative) risk assessments (Lindhe *et al.*, 2009; Lindhe *et al.*, 2012). However, at corporate level, interactions occur between several "broad risk areas", including the ones related to business and reputational risks, making the application of these techniques difficult for the global analysis. In this regard, the holistic approach developed in this thesis gives a contribution to knowledge, through the foundation of the strategic risk appraisal on a systemic model where interactions between physical, financial and reputational risks are captured and analysed (Figure 6-3) using semi-quantitative methods. For example, 'inadequate long-term planning' was found to influence business sustainability (leading to poor resource allocation), business profitability (by making it difficult to secure returns on investments in case of asset overcapacity), water quality (in case of asset overcapacity) and water quantity (in case of asset under capacity).

Capturing the interactions between risks and establishing a multi-barrier approach to risk management is a tenet of good utility management in the water sector, since incidents are frequently characterised by multi-causality and interdependence in their effects (Pollard *et al.*, 2009; Hrudey and Hrudey, 2004). However, establishing a multi-barrier approach is usually developed at operational levels and, to our knowledge, no such approach has been developed before at corporate level. Existing methodologies, like COSO (2004), seek to identify controls for risk reduction, but these are appraised in isolation, not taking into account risks interdependencies. Here, we expand knowledge by developing and validating a way of identifying existing control barriers and risks interdependencies expressed in the influence diagram (Figure 6-4 and Appendix G). Furthermore, a deep characterization of these barriers was deemed essential, because keeping them robust is the essence of risk management (Carter, 2012). MacGillivray and Pollard (2008) advocated that control evaluation should address both criticality and the respective effectiveness, i.e., adequacy of design, management and operation. In this research, besides characterizing the control barriers in terms of their effectiveness and criticality, we also described them with respect to their vulnerability, because it also constitutes a powerful input to devise risk management strategies and priorities, supporting decisions from risk managers and the Board about which barriers should be reinforced, maintained and relaxed. This data was gathered from risk experts and, besides being graphically illustrated in the influence diagrams, it was registered in a database (Appendix G).

Though initially being developed with the purpose of recording the outputs of the semi-structured interviews, the database constitutes a powerful tool for risk management, in that it allows (i) the registering of the different inputs; (ii) the detection of inconsistencies between different experts' views; (iii) the statistical analysis of the control barriers (e.g. which barrier is the most frequent?); and (iv) the automatic production of forms / individual records for each of the events, exposures and harms of the diagram (n=65). Ultimately, the database enables the comparison and extraction of information out of the data – thus, generating traceable corporate knowledge. For example, querying the supporting database (Table 7-1) shows a number of critical barriers at EPAL that are not performing at their highest efficiency and that are highly vulnerable, such as increasing the water supply system flexibility, having readily available alternatives in case of a failure in the supply of chemicals and other materials, having robust contingency plans, etc., hence suggesting that management strategies should address these issues. Table 7-1 shows that keeping a good relationship with the media, maintaining the robustness of online monitoring (SCADA) and keeping water treatment plants efficient are the most effective, critical and less vulnerable barriers.

Table 7-1 - Example of queries in the database supporting the systemic model

	E (1best)	V (1less)	C (C/NC)
- AM (asset management) best practices	1	5	C
- Business continuity -contigency plans	3	5	C
- C.Bode reservoir management commission	3	5	C
- Increase system's flexibility	3	5	C
- Ready available alternatives	5	5	C
- Relation with EDP	3	5	C

	E (1best)	V (1less)	C (C/NC)
- Media relationship	1	1	C
- Online monitoring	1	1	C
- WTPs' efficiency	1	1	C

By reference to existing methodologies, Vlek (2013) pointed out the need for a transactional model, where risks are not appraised in a static way, but rather in a dynamic relation with internal controls. We claim the approach developed in this thesis meets Vlek's call for such a model, because though the influence diagram should remain stable for many years – since strategic objectives are set for the long term – the systematic revisiting of existing barriers provides the intrinsic dynamism, countering complacency which is one of the major causes for incidents to occur (Pollard, 2008; MacGillivray and Pollard, 2008; Carter, 2012). This innovation provides a novel solution to the well-recognised fragmentation between operational and strategic risk appraisal in organisations.

We also highlight the inclusion of risk factors in the analysis, i.e. contributing factors that may alter the respective likelihood (Hokstad and Steiro, 2006; ISO 31000, 2009) - Figure 6-2. Whilst not novel, the fact that these were assessed separately from the events, exposures and harms represents a different approach from the ones embedded in ERM frameworks, which allow for secondary risks to be added directly in the analysis (Schiller and Prpich, 2013). The reason for our distinctive approach is simple. We realized these risk factors (e.g. inadequate data/information management, legal non-compliance, lack of communication within and between departments as well as outside the company, poor human resources management and inadequate governance) could not be considered as initiating events that pose harm to strategic risks, but rather they act as "meta-risks", affecting the robustness of existing barriers and, consequently, the likelihood of events, exposures and harms. For example, keeping abreast of asset management best practice is seen as highly vulnerable due to the fact that 200 out of the 700 employees (approximately) are aged 55 or more, thus being expected to retire within the next ten years, and no transmission of knowledge to new employees is foreseen, due to legislative measures that impede state owned companies recruiting new staff (Appendix E) – thus, giving way to potential human reliability flaws (Pollard, 2008; Wu *et al.*, 2009) that may have an impact on diverse exposures and harms to strategic risks.

Another insight from this research is related to the role of the influence diagram in estimating the likelihood of strategic risks, as presented in Figure 6-5. The novelty and significance of this is best illustrated by its comparison with existing risk management frameworks. First, in the use of causality between events, exposures and harms - as well as the characterization of existing barriers and risk factors - to inform likelihood of risks (Figure 6-5). Existing strategic risk management frameworks tend to focus directly on the likelihood of harms regardless the underlying processes or pathways, which impede risk reduction measures to be targeted at their root causes (MacGillivray and Pollard, 2008). Secondly, novelty in visualising the influence diagram coloured allows risks with a natural low likelihood – e.g. “Water Quantity” – to be distinguished from those where the likelihood is low due to the existence of control barriers – e.g. “Water Quality” - Figure 6-5. This is an important observation, in that focusing only on the likelihood of risks – as often preconized by existing frameworks - might lead the Board to become comfortable with risks having a low likelihood, even though some are naturally low likely to happen whilst others may be highly dependent of control barriers – and thus, requiring particular attention on the maintenance of those barriers.

A further innovation of the influence diagram, and the interdependencies it records, is that by allowing a broad overview of the interactions between risks to corporate objectives, as well as of the existing control barriers along the pathways, it constitutes a natural starting point for discussion between the Board and risk managers. This is significant because communication shortcomings between these actors were found to be among the main causes for second generation methodologies of strategic risks comparison to fail (Prpich *et al.,* 2011). On the other hand, current methods to aggregate risk within ERM are semi-quantitative, using ordinal assessments of risk in a risk matrix (Schiller and Prpich, 2013) which, despite their potential to be used as a basis to enrich discussions about the risks, may be opaque in revealing the underlying connection between operational and strategic information. Though recent methodologies advise the writing up of narratives to complement the interpretation of risk matrices (Prpich *et al.,* 2011), we can still argue that the influence diagram developed in this research is a stronger piece for the purpose of promoting discussions between all the parties in terms of the likelihood of risks, because of the huge amount of information that is provided in one single sheet (Figure 6-5). Ultimately, the influence diagram is used to inform a Board, who are not expected to perform a detailed analysis of enterprise risk but rather to oversee what drives strategic risk and ensure these drivers are managed – which is often the most challenging and important aspect of risk oversight (Caldwell, 2012).

Finally, the influence diagram enables the process to be transparent and repeatable under the same basis of analysis, which is a proxy for its credibility (Wiedemann *et al.*, 2013; FAO/WHO, 2009; ISO 31000, 2009; Hokstad and Steiro, 2006). Actually, the process was repeated in this own research, as the influence diagram was used to test EPAL's strategic risks against plausible future scenarios (Appendix I). The novelty here is found by reference to other ERM frameworks, where the results of likelihood and consequence are frequently processed in a "black-box", not allowing the respective trace back and, therefore, jeopardizing the discussions with the Board.

7.4 Risk "heat-maps" as a basis for discussions with the Board

Despite the strengths of the influence diagram highlighted in the previous chapter, it does not show the consequences associated to risks. Hence, there is still a need to construct a risk diagram, or "heat-map", presenting the evaluation of likelihood and impact of each strategic risk. In this thesis, the results of such evaluation were expressed by the central position of an ellipse, where the length of the vertical and horizontal axes reflects the uncertainty in the respective assessment (Figure 6-6). The use of risk matrices where risk would be tightly classified as "high", "medium", "low" or similar, was deliberately avoided here because of the variety of data and the respective range of uncertainty the nature of this SRA embodies (Cox, 2008). Instead, the "heat-map” can be regarded as a high-level risk diagram that enables the Board to compare the relative positioning (and sizing) of the risk ellipses, and to promote rich discussions, which should be supported by narratives on the character of the risk and on current risk management strategies - Appendix G (Prpich *et al.*, 2013). For example, the “heat-map” shows a moderate to high likelihood that business sustainability is highly compromised, i.e., that the company will be able to accomplish its mission in the next 20 years but struggling with high economic or financial constraints – this may be due to lack of financing, to difficulties in raising self-capital and to the uncertainty in the sector, as referenced in the narrative.

Significant probability heuristics and biases especially operate under limited information conditions (Vlek, 2013), so in the current approach an effort was made to obtain as much information as possible (Slovic, 1987), drawing on data originating from different grounds: scientific information, past data, fault-tree or scenarios models and empirical knowledge. As an externality, this enabled the destroying of some “myths” in the company. For example, it was a current thought at EPAL that the two free-surface flow trunk mains presented a very high likelihood of contamination. Instead of classifying the likelihood of this exposure based on that assumption, water quality risk experts were urged to investigate the results of the lab analysis made over recent years to the water quality on these trunk mains, having come to the conclusion that the number of non-compliances with legal requirements found in those trunk mains was negligible. In order to achieve a high degree of transparency, the reasons behind the likelihood estimation of each event, exposure or harm, were recorded in the database (Appendix E).

Impact evaluation evidenced a strategic objectives’ values hierarchy (Vlek, 2013). For example, in this research compromising “reputation and trust” does not present “catastrophic” consequences when compared to other objectives (Table 6-3). Thresholds for the different classes of consequences were defined taking into account that this exercise was being held at strategic level, despite being fed by operational and tactical data. Hence, plausible worse case situations as well as the reaction time – also known as risk clock speed (Caldwell, 2012) - were addressed. Taking the reliability of supply as example, the questions posed were: "what would be the worst case of a critical infrastructure failure? Could it be considered 'catastrophic'?". For the consequences of not having enough water quantity to supply, a threshold of six months was considered, taking into account the estimated time to implement new abstractions or transfers from other water sources or transport systems. This is important because, as mentioned above, the same event may occur with less significant consequences at operational or tactical levels. Hence, we can infer that the construction of the consequence scale is a possible way to differentiate risks at the three levels.

On the other hand, consequences' criteria (or attributes) were chosen for each objective envisaging the balance between totality and usability (Willis *et al*., 2004; Prpich *et al*., 2011; Curtis and Carey, 2012), which is often challenging. In this work (Table 6-3), consequences were described by their type, extension (magnitude) and duration (including irreversibility) – we named this approach as "TED". Here, we turned again to decision theory. Keeney (1992) distinguishes three types of attributes to measure objectives: (i) natural attributes, i.e., those that have a common interpretation to everyone and arise naturally from the objective – for example, if the objective is "minimize cost", a natural attribute would be "cost measured in euros"; (ii) constructed attributes, used to characterize objectives to which it is difficult to come up with natural attributes, like "improve the image of the corporation"; in these cases, attributes play a double important role, as besides providing a way to measure the objective, they essentially define what is meant by the objective and, therefore, should be developed specifically for a given decision context; and (iii) proxy attributes, indirect attributes used when it is very difficult to identify natural or constructed attributes. In this research, given the overarching definition of the strategic objectives, we used constructed attributes (Table 6-3).

Though the use of attributes to describe the character of harms is not new, the insights from this research are: the "TED" approach to balance simplicity and comprehensiveness; the linkage with decision theory to generate constructed attributes; and the clear need to make consequence scales specific for the organization (Table 6-3).

On the whole, we argue the “heat-map” mirror the likelihoods assessed through the systemic model in combination with the associated consequences of strategic risks, providing an intuitive way to compare them (Figure 6-6). Nonetheless, beneath each risk ellipse there is a golden tread of data and information resulting from an analytic-deliberative approach (Appendix G) that encompasses a synthesis of scientific expertise and value orientations (Kleink and Renn, 2002; Willis *et al.*, 2010). To our knowledge, this is the first such analysis, performed in a water utility, which has informed strategic risk appraisal in this way.

7.5 Representing uncertainty

As with most SRA tools, this approach is subject to uncertainty. Ascough *et al.* (2008) introduce four types of uncertainty: aleatory, epistemic, decision-making and linguistic. In our approach, the inherent variability of the events constitutes an aleatory uncertainty. Gaps in the knowledge of risk experts and risk managers to correctly identify the relations in the influence diagram or to estimate the corresponding likelihood and consequences are expressions of epistemic uncertainty, the same applying to the construction of the model itself, which is only a representation of reality. The subjectivity inherent in the value judgement for choosing the strategic objectives as well as the consequence scale may be associated with decision-making uncertainty. Due to the role of the risk co-ordinator, which contributed to deriding vagueness and ambiguity during the semi-structured interviews and the workshops, linguistic uncertainty was expunged.

The elliptic shape of risks in the “heat-map” reflect the aleatory uncertainty through the size of the horizontal and vertical axes, and Figure 6-6 evidences this is far higher for consequences than for the correspondent likelihood. It also evidences that “compromising business sustainability”, “compromising reliability of supply” and “compromising business profitability” are the risks with a higher aleatory uncertainty in terms of their likelihood of occurrence. This may be due to the number of events over which the company does not have much control and that are difficult to predict. For example, the lack of stability in legislation and economic regulation often does not provide the stability needed for the investment (Hecht *et al.*, 2012) and may exacerbate social, environmental, economic or business risks (Morrison *et al.*, 2010).

Epistemic and decision-making uncertainties were registered in the database (Appendix G) and classified as “low” – if there was scientific or empirical evidence; “medium” – if there was no empirical or scientific evidence, but a high level of agreement among experts existed; and “high” – when there was no empirical or scientific evidence and a low level of agreement among experts. Classes of “High” and “Moderate” uncertainty were mainly associated with financial, regulatory and reputational risks, which may be explained by the fact that, for technical risks, there is more scientific or empirical evidence available (e.g. metering, climate information, water quality assessments, etc.) than for social risks (Renn, 2008a; Mason, 2013). Overall, the results show that the degree of epistemic and decision-making uncertainty behind this assessment is “low”, which is not surprising, given the:

- global “high” level of weight of empiric and scientific evidences (Pollard *et al.*, 2008) covering the events, exposures and harms to strategic risks in the company - Appendix B;
- experience, background and day-to-day work of the selected risk managers and experts (Appendix A). In fact, citing Rosness (1998), MacGillivray and Pollard (2008) advocate that “the legitimacy of risk analysis depends largely on the capacity of staff to critically evaluate available information and to supplement it with their own knowledge”;
- rationale for the way in which the groups in the workshop were formed (e.g. gathering experts whose knowledge covered the whole set of events, exposures and harms associated with a given strategic risk) and moderated (Appendix F) by specialists from Cranfield University.

These items are also pointed out by Wiedemann *et al.* (2013) as providing credibility of risk assessments.

Capturing and communicating the degree of uncertainty implicit in risk assessments is important, because the final decision-makers (the Board) need to acknowledge to what extent they can rely on the results, based on which a range of strategies will be addressed, probably involving significant costs. Although uncertainty is intrinsic to risk, ideally it should be kept as low as possible. However, offering a systematic treatment of uncertainty in order to improve the management of uncertainty in decision making processes is neither simple nor consensual (Krayer von Krauss *et al.*, 2006; Patt, 2007; Pollard *et al.*, 2008). Despite not being focused on addressing this challenge, the approach developed in this research succeeded in capturing, communicating and keeping epistemic and decision-making uncertainty low, given the aforementioned reasons.

7.6 Development of future scenarios to cope with the evolving character of strategic risks

Strategic objectives do not vary from day-to-day. Instead, they should be stable over years (Keeney, 1992). Strategic risk management should therefore be aimed at the mid and long-term - particularly in the water sector, where assets are designed to last 25 to 50 years. However, there is little evidence that this has been done before in an integrated way, and the outcomes of strategic risk analysis tend to represent a “snap-shot” in time, regardless the fact that strategic objectives are set for the long-term. On the other hand, scenario planning has been used to inform strategic planning in utilities, most of the times regarding a specific issue – e.g. climate change –, but it misses the link with risk management due to the unaccounted perspective of the projected likelihood. As pointed out by Koivisto *et al.* (2009) and further developed in chapter 2.5, risk and futures assessments are in many ways parallel, but in practice these two areas of research are seldom linked.

The approach developed under this case-study represents a significant step forward in the integration of the two research fields and evidences the complementarity between them. Though future scenarios were developed using the well-known morphological analysis technique and risks were re-assessed using the systemic model again as a basis, the touching points between risk and futures were (i) the focal question (6.3.1.2) - “what are the plausible scenarios that provide a wide range of situations to test my risks against?”; (ii) the scale to evaluate consequences (Table 6-3) – its aptitude to assess risks both in the present and in the future results from the fact that it is related to the strategic objectives (and hence, with the values behind them), which are set for the long-term (Keeney, 1992); and (iii) the dynamic evolution of strategic risks forward in time (Figure 6-9, Figure 6-10 and Figure 6-11).

Besides the most obvious one – enabling the reassessment of baseline risks under given future scenarios – the developed approach offers four specific innovations:

1) As the morphological analysis was carried out involving the risk experts (Appendix F), it constituted an opportunity to provide them with training on this subject in particular and on futures science in general, leading to a change in the current mind-set – which was focused on planning the future using projections from past trends.
2) The linkage between risks and futures was shown to be an effective vehicle to integrate the conclusions of existing studies already carried out by EPAL into strategic risk management (e.g. climate, demographic and land use changes). This holistic perspective contrasts with the current practices where adaptation measures are proposed and managed in siloes, as a response to events triggered by only one single driver, despite being related to other drivers as well – a difficulty noted by Adger *et al.* (2005) regarding climate change. For example, this case study shows that under the “Water scarcity” scenario, most of EPAL’s strategic risks will increase: besides, of course, compromising supply with adequate “water quantity”, “business profitability” will decrease due to a reduction in sales; “reliability of supply” will be affected because local abstractions may be suspended due to shortage of water or water quality problems (this shows how risks are interdependent); and “reputation”

may be affected if customers do not get the service levels they are used to and adequate measures are not adopted in a timely way (Figure 6-9).

3) It enables the unveiling of opportunities that arise from each scenario, which should be accounted for by the Board (Defra, 2008), alongside the threats associated with risks (Koivisto *et al.*, 2009). For example, in this case study some of the opportunities that arose from the water scarcity scenario (Figure 6-9 and Appendix I) are that the likelihood of having competition in water supply by municipal clients of EPAL will decrease, since their water sources are far less resilient to climate change than the ones of EPAL; and the image and reputation of EPAL can improve, if the company takes timely adaptation measures and communicates them adequately.
4) In this approach, long-term planning is not based on pre-defined alternatives (for example, ad-hoc “what-if” questions), but sets-off from an open base of possibilities, because alternatives, i.e., the chosen scenarios, emerge from the morphological analysis (Figure 6-7). This means the emphasis is put on “what can we learn about future impacts on our strategic objectives” – a value-focused thinking, starting with the best potential outcome, though demanding a higher cognitive effort – instead of “what alternative futures with an impact on strategic objectives do we want to explore” – an alternative-focused thinking, that starts with a set of alternatives and then tries to make the best out of it (Keeney, 1992).

The results of the analysis proved to be consistent, showing that in the “financial resources’ scarcity” scenario (Figure 6-10), the relative position of strategic risks does not change much from the baseline, which is explained by the fact that Portugal is already facing an economic crisis at present. Not surprisingly, a “strong economic growth” scenario (Figure 6-11) will lower all risks. It should be noted that, by including Cross Consistency Analysis in the methodology, the morphological approach makes it easier to ensure the consistency of the final results, unlike other methods for scenario building.

The holistic, systemic and long-term perspective adopted in this approach significantly contributes to improving water utilities' strategic planning, by linking two research areas that have been operated separately. One could speculate that it meets the emerging third paradigm in futures science – a systems and cognition oriented paradigm, enabling a new understanding of dynamic systems through an applicable interdisciplinary methodology (Kuosa, 2011).

7.7 Deliberative approach, enhancing organizational risk culture and avoiding bias

Many authors argue that both in risk management and in futures' planning, the process is as important, if not more so, than the strategies themselves (Wack, 1985 in Brummell and Greg MacGillivray, 2008; Amer *et al.*, 2013; Koivisto *et al.*, 2009). Although these two aspects overlap, the framework developed here provides a holistic, systematic way to manage long-term risks, whereas the process affords a transparent and structured means to engage diverse expert and stakeholder perspectives in judging the implications of such information (Powers *et al.*, 2012).

This research employed an action-oriented approach, necessarily involving various levels of the organization (Coghlan and Brannick, 2005), especially because the setting of strategic objectives suggested almost every department at EPAL should be involved in the analysis. The value of doing this type of research in 'testing mode', unfolds in various ways.

First, it requires high levels of engagement among the researcher's colleagues (Coghlan and Brannick, 2005) which, despite being hugely challenging to undertake (Coghlan and Brannick, 2005), contributes to raising risk management awareness in the company. This research confirmed that the involvement of the Board from the beginning, as well as the knowledge the researcher had of the organization were crucial to securing the necessary commitment from risk experts throughout the process – two of the key-drivers for successful ERM implementation presented by Frigo and Anderson (2011). The high level of commitment of the team engaged is expressed by their contributions in the interviews and the workshop. This is patent in the way the influence diagram evolved from a preliminary categorization of events and harms, to the final events, exposures and harms diagram (Appendix C and Figure 6-3). For example, in an initial version of the influence diagram, “critical infrastructures’ unavailability for an extended period” was caused only by “critical infrastructures’ failure”, while in the final version this “harm” was associated with “critical infrastructures’ failure”, “power outage”, “failure in the supply of chemicals, materials, equipment, contractors” as well as “insufficient human resources available to operate the system”. Somehow, we may infer this is a testament to the collegiate culture at EPAL and to the risk management maturity of the company. Reviewing the risk management capability maturity model presented by MacGillivray and Pollard (2008), EPAL positions itself between levels 2 (repeatable) and 3 (defined) processes in risk management across business functions, which proved sufficient to implement the methodology developed and ensuing outcomes. We speculate that any lower maturity would increase the difficulty in reaching consensus, due to a lack of common culture (Tavares, 2012). Therefore, we admit the effect of the shared organisational culture (Summerill *et al.*, 2010) played a critical role in the success of this approach at EPAL.

Secondly, this approach allowed the unveiling of relevant tacit risk knowledge, side-by-side with formal and codified information (Appendix G), contributing to knowledge generation. Despite being considered a key challenge by Nonaka and colleagues (Schiller and Prpich, 2013), “stakeholders consultation is a golden opportunity to gather insights that can’t be manufactured and secure goodwill that can’t be bought” (Defra, 2008) forming one of the key outputs of the risks and futures approaches involving people networking, where the developed knowledge is more than the sum of its elements (Koivisto *et al.*, 2009). Moreover, bringing together experts and practitioners among participants provides a diversity of experience that may be considered an asset for an institutional exercise (Saritas and Nugroho, 2012).

Since the management of strategic risks is assured by different organisational departments, this approach challenged the perceptions of risk management across organisational siloes, by sitting around the same table engineers, financial and image managers. We speculate that, in accordance with critical realism, this enables the shortening of the unavoidable gap between the social perception and the technical reality of risks. Having the knowledge opened to everyone also improves the culture of risk and communication across business functions within utilities, ensuring its pervasiveness in the company (Allan *et al.*, 2013).

Finally, the approach can provide high levels of political confidence that there is a firm understanding (and active management of) strategic risk within the company, now and for the future. This was especially evident in the validation workshop among those groups dealing with reputation and business profitability issues, who provided highly creative responses on human and organizational barriers identification for strategic risk management (Figure 6-4).

The summary is that the in-house / action-oriented research methodology proved an appropriate vehicle for this research project. We anticipate that it could not have been undertaken by external parties nor could it have been done remotely at distance from EPAL.

This said, the action research approach may lead to some bias, as well. Maxwell (2009) calls attention to the fact that despite the inherent advantages, bringing the experience and knowledge of the researcher - Reason and Bradbury's (2001) "first voice" - into the research may lead to distortions in the methods and in the interpreting of the results. On the other hand, the "second voice" – here, primary risk managers - were the heads of financial, planning and management control, operation, maintenance, asset management, logistics, water quality control, human resources, customer relations, design and works, information technology and organisational development departments. Each of these managers also appointed technical domain risk experts, so there is also the possibility for cognitive bias in the assessment of causal chains, barriers and their effectiveness. Vlek (2013) mentions the dangers of failing to recall relevant events, or of misperceiving causal chains. There is also the possibility of exaggerating or underplaying the likelihood and consequences evaluation (Renn, 2008b).

It has been suggested that risk is an ‘exercise in power’ (Slovic, 1998), either because risk managers know that by augmenting the relevance of their risks, they will receive higher budgets to manage them, or because they suppress their professional anxieties so not to incur extra costs for the organisation (Vlek, 2013). On the other hand, ‘group think’ may cause less vocal participants to be dominated by opinionated leaders (Vlek, 2013; Powers *et al.*, 2012). Additionally, while individual interviews reflect consistent and coherent opinions (even if deliberately exaggerated), the need to reach consensus in a group may cause opinions to become incoherent (Cox, 2012).

In this methodology, the researcher adopted a “critical subjectivity” attitude (Reason, 1988 in Maxwell, 2009), i.e., an awareness in which her primary experience was not suppressed nor allowed to overwhelm the research, but rather seen as raising consciousness and used as part of the process – e.g. drawing the first draft of the influence diagram (Appendix C), evoking the existing studies (Appendix B), gathering the right people in the workshop groups (Appendix F), etc. Special care was taken during the interviews, so that the researcher’s own point of view did not influence the answers given by her colleagues or the process of transcribing them. For example, part of the answers was directly registered on the schematics of the influence diagram, thus reducing the risk of misinterpretations. As for the “second voice’s” bias, given the interactions among strategic risks, experts from different departments critically analysed the same risks. Each was interviewed separately, and, if appropriate, at the end of the conversation they were asked to comment on different opinions about identical issues that had been gathered either in previous interviews with experts from other departments or in literature or existing studies. This process smoothed possible biases. Triangulation of the results was made by writing down the likelihood of events, exposures and harms estimated by the different risk experts in the influence diagram, allowing detecting inconsistencies, which were mainly solved during a second round of interviews. Then, transparency (ISO 31000, 2009; Hokstad and Steiro, 2006) and validation were assured by joining managers and experts from different departments in the same groups (Appendix F), and by providing each group with the same influence diagram and set of records characterizing the events, exposures and harms associated with the strategic risks. Positive group dynamics (Johnson and Johnson, 2000) was secured by moderators from the research team in each group (Appendix F). Given the extent of validation achieved through what Maxwell (2009) refers to as intensive, long-term involvement of the researcher; gathering "rich" data; validation of responses by peers and triangulation; we claim that this approach minimizes the possibility for bias - which is also a proxy for the credibility of risk assessments (Wiedemann *et al.*, 2013).

7.8 Generalization to other utilities

In accordance to an action-research project, the results in this thesis are not intended to be statistically generalizable but, instead, analytically generalizable (Yin, 1994 in Maxwell, 2009) or transferable (Guba and Lincoln, 1989 in Maxwell, 2009). They contribute to the development of a theory that can be extended to other cases (Becker, 1991 in Maxwell, 2009).

The similarity of dynamics and constraints to other situations as well as the presumed depth or universality of the phenomenon studied, are two of the features that lend credibility to generalizations (Hammersley,1992 and Weiss, 1994 in Maxwell, 2009). Regarding the validity of the proposed approach for other water utilities, or even for other sectors, it is possible to speculate that: (i) strategic objectives will not differ much from water utility to water utility; recognizing utilities from other sectors may have different strategic objectives; (ii) the influence diagram, as well as the definition of the consequences' scale, is EPAL-specific, although they are easily adaptable to other water utilities; in other sectors, relevant events, exposures and harms are expected to significantly change, but the base concepts of the approach developed may be applied; (iii) the key-drivers for future scenarios will likely be the same for other water utilities, and, again, are expected to be partially different for other sectors, although the general philosophy can still be applied. All this implies that although context is crucial, it is possible to generalize the lessons from this case study in a wider range of utilities.

Additionally, and despite the fact that CCA requires the use of software to compute the co-existence of projections associated with the different key-drivers, a further strength of this approach is its transparency for experts and the Board, given that the whole process, from the influence diagram to the side-by-side comparison of strategic risks in each scenario, through the choice of key-drivers and even the CCA matrix, is traceable, explainable and subject to challenge. These important issues (Dong *et al.*, 2013; Durance et Godet, 2010) emanate from using relatively linear and easy-to-understand methods, such as influence diagrams and the morphological analysis. "Simple is beautiful", as stated by François-Serge Lhabitant (Gregorious, 2007) in his set of rules to manage risk models, making it easier to replicate this approach in other cases.

7.9 Summary

7.9.1 Contributions to knowledge

This thesis contributes to the theory and field of risk management in a number of ways. By addressing the research question "*How can a holistic approach linking strategic risks assessment and future scenario planning in water utilities be set up?",* three key contributions include:

1) The development, illustration and validation of a top-down / bottom-up approach interconnecting operational, tactical and strategic risks and capturing the respective interactions.

   To our knowledge, no such approach has been previously developed. Frequently, operational and strategic risk analyses are performed in isolation of one another for a host of reasons (e.g. the engineering versus a managerial focus), and there is rarely a truly systemic approach to assessing the water supply system. For example, engineering and asset risk analyses, including the human dimensions of managing risk (Wu *et al.*, 2009), rarely appear to inform strategic risk management activity directly. Current methodologies adopted by other utilities towards strategic risk include the use of "Red-Amber-Green" corporate risk registers, the use of risk "heat-maps", and 5x5 risk ranking exercises (Pollard, 2008; ISO 31000, 2009).

This novel approach is significant because it overcomes the limitations found in the (still limited) implementation of risk management at strategic / corporate level: the need to improve communication between experts, managers and the Board (Summerill *et al.*, 2010; Allan *et al.*, 2013), in order to secure a correct alignment of risk management across operational, tactical and strategic levels; and the need to integrate, harmonize and capture the interactions between the analyses of the different physical, regulatory and financial risks (Means *et al*., 2010; Hamilton *et al.*, 2006; Renn, 2008b; Larson *et al.*, 2009; ISO 31000, 2009; Prpich *et al*., 2011; Frigo and Anderson, 2012; Schiller and Prpich, 2013). Hence, the interconnection between strategic risk and the operational reality of risks in the business shown in the developed approach (Figure 7-2) helps safeguarding confidence from stakeholders and regulators that corporate risks are being properly managed. This methodology expands the prior art by illustrating *how* a systemic analysis of risk can actively inform the corporate priorities set by a utility.

2) Assessing long-term risks.

To our knowledge, no other approaches have been developed to assess risks in the long-term and in a holistic fashion. Scenario planning has been used as a strategic tool, separately from risk management, generally focusing on one single issue and often developing from extrapolations of past trends, which have been shown to be unsuitable for long-term analysis.

The novel approach developed here provides a framework to assess risks in the long-term, which is significant because corporate objectives are set for the long-term and may change under different conditions of political, economic, social, technological, legal and environmental drivers. This is especially relevant for capital intensive industries like water utilities, where assets are designed to last around 25 to 50 years. This novel approach expands prior art because until now, techniques for SRA in the mid and long-term were still in their infancy (Prpich *et al.*, 2013), and the existing SRA or ERM frameworks have not accounted for the long-term evolving nature of strategic risks.

3) Linking risk and futures.

   To our knowledge, there are no approaches in the literature that establish the linkage between risk and futures presented in this research. Future scenarios have been used to support strategic planning, but they concentrate only on projected consequences, thus missing the link with risk management due to the unaccounted perspective of the projected likelihood.

   Despite risk and futures assessments being parallel in many ways, in practice these two areas of research have seldom been linked. The approach developed under this case-study represents a significant step forward in the integration of the two research fields and evidences the complementarity between them.

7.9.2 Contributions to ERM practice in water utilities

The critical strengths of this research work for water utilities – and for EPAL, in particular, are that (i) it builds a deep understanding of how the key risks are interdependent and how they impact, as a whole, on the strategic objectives of the company; and (ii) it provides a long-term perspective of the baseline risks, by reference to a set of future scenarios that are company-generated.

This approach constitutes a useful tool for strategic / master planning, which may be presented to the Board in a simple and intuitive way, despite the solid foundations of the underlying analysis. It also builds on in-house expertise, promoting the dissemination and pervasiveness of risk management within the companies and, on the other hand, allowing unveiling of existing knowledge, making it explicit and more useful for the organization.

The process is transparent (auditable) and repeatable, and though the development of such an approach is intensive and time-consuming, the assembled set of data and analyses shall be reasonably long-lasting. In addition, and where possible, it builds on the results of available analyses, thus providing a convenient framework within which to scope out and integrate the conclusions of the existing studies. It does not claim to replace the function-specific approaches to risk management (e.g. engineering; drinking water quality management; asset management; emergency management; occupational health and safety; financial analysis) that are carried out at operational or tactical levels, but rather to bring the respective outcomes to a higher, strategic level of analysis. Moreover, by including in the analyses business and reputational risks, the developed approach may lead to a redefinition of the current role of engineering thinking in strategic planning.

By linking risk and futures, this approach challenges the openness to new future possibilities by changing mind-sets, building trust among actors and developing better preparedness for the change. It also generates knowledge by creating an understanding and sharing it in networks of people (Koivisto *et al.*, 2009).

Ultimately, and contrasting with the traditional siloed risk management practice, this novel approach contributes to increasing overall business efficiency and sustainability, by permitting the optimisation of risk-reduction options, i.e. the allocation of the right resources to the right risk barriers. It enables the adoption of a preventative attitude towards risk whilst being alive to opportunities, thus generating trust from the customers, the regulator and the shareholders.

8 CONCLUSIONS

As presented in chapter 3, the overarching aim of this research was to develop and test a novel methodology that allows the Board of water utilities to appraise strategic risks and to gain a long term perspective on this baseline set of risks.

In order to achieve this aim, a number of research objectives were defined:

- Objective 1: To examine the existing methodologies for SRA in order to detect the gaps to be filled and the benefits to be expanded.

  Achievement of objective 1 is described in chapter 2. Main observations are that: (i) setting strategic goals is the first step water utilities need to take and establishing risk tolerability remains a complex subject (chapter 2.2.1); (ii) detailing the analysis as much as possible, in order to make it defendable, while keeping it simple enough for decision-makers to understand is one of the main challenges (chapter 2.2.1); (iii) there is the need to improve communication between experts, managers and the Board (Summerill *et al.*, 2010; Allan *et al.*, 2013) – chapter 2.2.2; iv) a third generation of SRA tools is now emerging, focusing on the delivery of a set of visualizations that can provide a base for rich discussions and understanding of the risks, instead of delivering a “top-ten” ranking (chapter 2.2.3); v) a step change is still required to, like other sectors (e.g: electricity), further integrate water risks with business, financial and other risks (Frigo and Anderson, 2012) (chapter 2.2.3); and vi) ERM has gained increased popularity but existing methodologies are still immature (Schiller and Prpich, 2013) (chapter 2.2.3). Chapter two also evidences that in respect of futures science (i) *systems thinking* paradigm is coming to an end, giving way to *systems and cognition* paradigm, aiming to “identify structures of network, optional connections, constraints and contexts” (Snowden, 2010 in Kuosa, 2011), enabling a “new understanding of dynamical systems” and developing “applicable interdisciplinary methodology” (chapter 2.3.1); ii) the process of building futures starts with the identification of a focal question (chapter 2.3.2);

and iii) mega-trends such as climate, land use and demographic changes are usually analysed separately (chapter 2.3.3) and not connected to risk analysis. The literature review allowed the conclusion that risk management and scenario planning evidence many commonalities (chapter 2.5) but, in practice, these two fields have run in parallel.

- Objective 2: To investigate how the company's team (members of the Board, risk experts and risk managers) shall be assembled and involved throughout the process.

  Chapter 5.2 describes the way EPAL's team was assembled and engaged throughout the project. As identified by fulfilment of Objective 1, there are a number of potential organisational cultural barriers to SRA implementation, so it is therefore important to understand what positive elements supported this SRA implementation at EPAL. The main contributing factors for securing the necessary commitment from risk experts throughout the process were the involvement of the Board from the beginning, as well as the knowledge the researcher had of the organization and of the people. Additional motivational factors were the explanation of the whole process to risk experts so they understood where their contribution fitted in, as well as highlighting these contributions in the outcomes of the research during the validation workshop.

- Objective 3: To explore how strategic objectives shall be identified.

  Prior to the construction of the systemic model, it was necessary to identify strategic objectives of the company – "risk of what, to whom" (Pollard, 2008). Chapter 6.1 evidences the need to properly distinguish between strategic, fundamental and means objectives. Strategic objectives are "the decision makers' ultimate end objectives, providing common guidance to all decisions", and "should be stable over years" (Keeney, 1992). In this research, these objectives are physical (supplying wholesome, safe and reliable water), management (guaranteeing business sustainability and profitability) and reputational (image and trust).

- Objective 4: To construct a holistic, systemic model to assess strategic risks in the present (baseline).

  Building the systemic model resulted from an analytical-deliberative approach, enriched by risk experts' knowledge and information gathered in existing studies. Although drawing events, exposures and harms pathways is not new, applying at a strategic level and capturing interactions between risks constitutes a novelty of this work (chapter 6.2). Also, the deep identification and characterization of existing control barriers in EPAL's system, namely in terms of their effectiveness, criticality and vulnerability (Figure 6-5 and Appendix G), constitute a powerful input to assess the likelihood of strategic risks. It proved to be a way to interconnect operational, tactic and strategic risk analyses, thus providing a significant contribution to knowledge. In combination with the consequences' assessment, the systemic model revealed to be a useful tool for managers and the Board, in order to support their decisions about which barriers should be reinforced, maintained and relaxed.

- Objective 5: To investigate how the futures' science can be interconnected with SRA.

  The approach developed under this case-study represents a step forward in the integration of two research fields – risks and futures – and evidences the complementarity between them: future scenarios were developed and strategic risks were re-assessed for each scenario. Drawing on the conclusions from the literature review (chapter 2.5) and having fulfilled research objectives 3 and 4, it was possible to infer that the touching points between risk and futures were (i) the focal question (chapter 6.3.1.2) - "what are the plausible scenarios that provide a wide range of situations to test my risks against?"; (ii) the aptitude revealed by the scale of consequences evaluation (Table 6-3) to assess risks both in the present and in the future, because this scale is associated with strategic objectives, which are set for the long-term (Keeney, 1992).

- Objective 6: To undertake the construction of future scenarios and to reassess strategic risks in the future.

  Chapter 6.3 describes the steps towards the construction of future scenarios. Using the morphological analysis, four scenarios were built: reference scenario, water scarcity, financial resources' scarcity and strong economic growth (Figure 6-8). Baseline risks were then re-assessed by challenging the influence diagram under each scenario (Appendix I). This approach enabled the evaluation of both future risks and opportunities, permitting the adoption of a preventative attitude towards risk management. To our knowledge, no such approach has been implemented before.

- Objective 7: To develop a way of presenting baseline risks assessment as well as the way risks will change in the future.

  The visualization of the results plays a very important role, as it is the basis for discussion between the different actors. In this approach, the outputs of the baseline strategic risks assessment are intentionally represented in a simple, concise way, so that it may support rich discussions with the Board. These outputs (chapter 6.2) are (i) the influence diagram, with and without the control barriers (Figure 6-3 and Figure 6-4), allowing a broad overview of strategic risks and their interconnections; (ii) the influence diagram coloured from green to amber and red, reflecting the likelihood of the events, exposures and harms (Figure 6-5); this not only supports the estimation of risks' likelihood but also permits the distinguishing of the risks with a natural low likelihood from the ones where the likelihood is low due to the existence of control barriers; and (iii) the "ellipses" diagram, or "heat-map" (Figure 6-6), where the axes reflect the aleatory uncertainty of the likelihood or the consequences estimation associated with each risk. Nonetheless, and because risks should also look at the context (Renn, 2008a), beneath these simple visual outputs, there is a consistent and comprehensive set of information, which can be consulted in a database (Appendix G) and is synthetized in a narrative for each of the risks, associated with the "heat-map" (Appendix G).

An intuitive way to present risks' evolution in each future scenario to the Board is by making the ellipses in the "heat-map" move dynamically in a Microsoft Office^{TM} PowerPoint presentation or in similar software. Besides the "heat-maps", the changes in the influence diagram coloured according to the likelihood of events, exposures and harms (Appendix I) are also worth showing, since these allow a better identification of the main factors that contributed to the change in the strategic risks evaluation. However, to be able to show these changes in a written document (such as this thesis), a possible way is to present the "heat-maps" of each scenario side-by-side with the reference scenario (Figure 6-9, Figure 6-10 and Figure 6-11), complemented by a short narrative (chapter 6.3).

The novelty and significance of the proposed methodology is marked by the discovery of new knowledge (interconnecting operational, tactical and strategic risk; developing a holistic systemic model for comparative risk assessment; assessing strategic risks in the long-term); the application of existing knowledge to new situations (applying future scenarios to risk management); the connection of previous unrelated facts (combining the methods for structuring objectives with that of constructing influence diagrams; pointing out the parallels between risk and futures assessments); the improvement of existing designs (detailing the meaning of "strategic objectives" for the purpose of risk analysis; characterizing the control barriers in terms of their effectiveness, criticality and vulnerability; assessing risk factors separately from events, exposures and harms; using constructed attributes to describe the character of harms through the "TED" – type, extension and duration – approach). This has been tested in EPAL – the oldest and largest water company in Portugal, which supplies around 2,9 million people – through prolonged and deep engagement with risk managers and experts from within EPAL's business.

Taken in concert then, this work represents:

- the first systemic analysis of operational, programme-level and corporate risk for a water utility;
- a bottom-up, expert led analysis of risk interdependencies across EPAL, addressing aspects as diverse as people, skills and succession planning, the reliability of the asset base, human resources policies and governance structures;
- the basis for long-term, strategic planning under changing conditions of climate, technology, legislation, among other mega-drivers.

By assessing risks in a systemic and holistic approach and coupling strategic risk with long-term scenario analysis, this methodology allows water utilities to enhance their strategic planning, better allocate resources, reinforce existing risk reduction measures and explore new opportunities in the short, mid and long-term. This enables utilities to become more efficient, proactive and resilient, with benefits in terms of access to safe and reliable drinking water at affordable cost for present and future generations; adequate returns on investment and business sustainability for shareholders; and safeguarding a good reputation and the confidence of government, citizens and the investment community for the Board.

We believe this research meets the three main elements identified by Coghlan and Brannick (2005) as appropriate to judge the quality and rigour of action research: "a good story; rigorous reflection on that story; and an extrapolation of usable knowledge or theory from the reflection on the story".

9 CRITICAL REVIEW AND FUTURE WORK

Looking back at this research work, it is noticeable that, on the one hand, some things might have been done differently; on the other hand, future work may be developed in order to further enhance the approach developed.

For example, the translation of likelihood and consequences of strategic risks from the influence diagram to the shape and positioning of the ellipses in the “heat-map” is not completely explicit. Therefore, developing tools to communicate the relations between influence diagrams, likelihood assessments, database information and “heat-maps” in a more clear way could be subject to further investigation, the main challenge consisting of finding the right balance between transparency and simplicity. Such tools would facilitate the dissemination and implementation of this approach in other utilities – keeping in mind, though, that the roles of human judgement, communication and validation are crucial in each step.

The development of future scenarios was not exempt from limitations, either. The number of key-drivers was reduced from 11 to eight (excluding the “givens”) due to restrictions in the CCA software, although there is a rationale behind the elimination of the three key-drivers. “Given”- climate change was based on a single global circulation model, the HadCM3 from Hadley Center, for IPCC scenarios A2 and B2, downscaled to EPAL’s region. The CCA matrix was mostly subject to individual judgment, although it was validated by a group of experts. Specific time frames for the futures were not identified; the analysis was just directed for a 30 year horizon, which corresponds to a specific type of scenarios – images of the future (Miles, 2007 in Saritas and Nugroho, 2012) -, whereby another possibility would have been to construct future history, i.e., a description of a future course of events. Finally, a scenarios validation workshop with risk experts did not occur, due to time constraints. Despite all of the above, results proved to be consistent and plausible – the decisive conditions for assessing credibility of scenarios (Amer *et al.*, 2013).

The way uncertainty is accounted for and presented throughout the approach developed may constitute a topic for further investigation. Though the sizes of risk ellipses in the “heat-map” reflect the aleatory uncertainty of the likelihood and consequences, they do not visually transmit the degree of epistemic and decision-making uncertainty behind such judgement (which is indicated in the Excel database). Therefore, this issue might be further explored.

Last but not least, it is worth stressing that risk management approaches encompass two main phases, as shown in Figure 2-1: the risk evaluation phase and the decision-making phase. The research herein undertaken solely focuses on the first phase, thus a topic for further investigation would be to explore how the results of this analysis linking risks and futures can be incorporated into the company’s long-term strategy – a critical step for utilities to make use of the full potential of the developed approach, uncovering its ability to deliver value.

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APPENDICES

Appendix A – EPAL's team involved

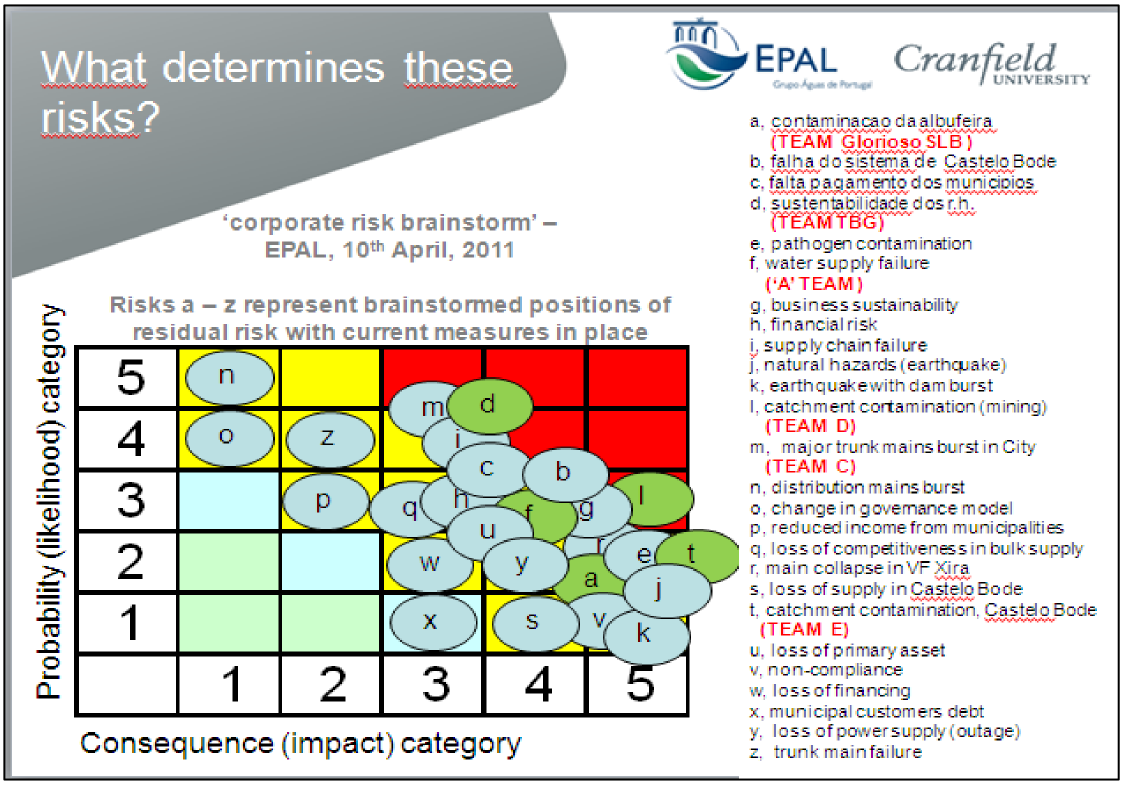
<table>
<tr><td colspan="4">Risk co-ordinator</td></tr>
<tr><td colspan="4">Ana Margarida Luis</td></tr>
<tr><td colspan="4">Management Board (the members of the Board changed during the course of the research)</td></tr>
<tr><td>João Fidalgo</td><td>A. Bento Franco</td><td>J. Loureiro</td><td>J. Manita Vaz</td></tr>
<tr><td>Rui Godinho</td><td>José Sardinha</td><td>M. Rosário Águas</td><td>Rosário Ventura</td></tr>
<tr><td colspan="4">Risk managers</td></tr>
<tr><td colspan="2">Infrastructures maintenance – DIR</td><td colspan="2">Joaquim Sereno</td></tr>
<tr><td colspan="2">Customers relations – DRC</td><td colspan="2">Luis Branco</td></tr>
<tr><td colspan="2">Asset management - DGA</td><td colspan="2">Francisco Serranito</td></tr>
<tr><td colspan="2">Organizational development - DSO</td><td colspan="2">José Figueira</td></tr>
<tr><td colspan="2">System Operation - DOP</td><td colspan="2">Mário Maria</td></tr>
<tr><td colspan="2">Water quality control - LAB</td><td colspan="2">Maria João Benoliel</td></tr>
<tr><td colspan="2">Planning and management control-PCG</td><td colspan="2">Anita Ferreira</td></tr>
<tr><td colspan="2">Logistics - LOG</td><td colspan="2">Barnabé Pisco</td></tr>
<tr><td colspan="2">Administrative and financial - DAF</td><td colspan="2">Marcos Miguel</td></tr>
<tr><td colspan="2">Projects and works - DGO</td><td colspan="2">Conceição Almeida</td></tr>
<tr><td colspan="2">Information Systems - DSI</td><td colspan="2">Paulo Rodrigues</td></tr>
<tr><td colspan="2">General Secretariat - SG</td><td colspan="2">José Zenha</td></tr>
<tr><td colspan="2">Juridical affairs - JUR</td><td colspan="2">Bruno Lopes</td></tr>
<tr><td colspan="2">Human resources - DRH</td><td colspan="2">Carlos Saraiva</td></tr>
<tr><td colspan="4">Risk experts</td></tr>
<tr><td>Nuno Medeiros</td><td>José Salgueiro</td><td>Helena Silva</td><td>Diana Constant</td></tr>
<tr><td>Cláudia André</td><td>Francisco Braga</td><td>Nuno Reis</td><td>Maria J. Capela</td></tr>
<tr><td>Marco Santos</td><td>Helena Saraiva</td><td>Sérgio Rodrigues</td><td>Guilherme Hora</td></tr>
<tr><td>Rui Neves Carneiro</td><td>Sofia Damião</td><td>Joaquim Broes</td><td>Alberto Martins</td></tr>
<tr><td>António Matos</td><td>Ana Amélia</td><td>Ricardo Silva</td><td>Ivo Joaquim</td></tr>
<tr><td>Paula Serrinha</td><td>Vieira Gomes</td><td>Luis Bucha</td><td>Paula Rodrigues</td></tr>
</table>

Appendix B – List of existing studies at EPAL

W-Smart
Underground sources protection zones (Grandwater)
Superficial water sources protection zones (protocol with UNL-New Lisbon University)
Contamination of C. Bode reservoir due to Panasqueira landslide (UNL-New Lisbon University)
Biodiversity in the surroundings of C. Bode Reservoir (Geota)
Seismic vulnerability of water tanks (protocol with IST-Technical University of Lisbon)
Vulnerability of above ground trunk mains (Tetraplano and LEB)
Analysis and acquisition of diesel generators (EPAL)
Disposal, refurbishment and renewal of Alviela Aqueduct (EPAL and Coba)
Pipe bursts' group (EPAL)
Water quality modelling in the distribution network (EPAL)
Emergency plans (EPAL)
Marketing campaigns (EPAL)
PSAT – Technical assets' security program (EPAL, EDP, REN, REFER, PT,…)
Water Safety Plan (EPAL)
Capital Investment Plan (EPAL)
Master Plan (EPAL)
Annual Accountants report 2010 (EPAL)
Adaptaclima-EPAL (FCUL – Sciences Faculty of Lisbon University)
Forecasting the failure probability for water mains (Cranfield University)
Application of COSO framework at EPAL (2011)

Appendix C – Preliminary versions of the influence diagram

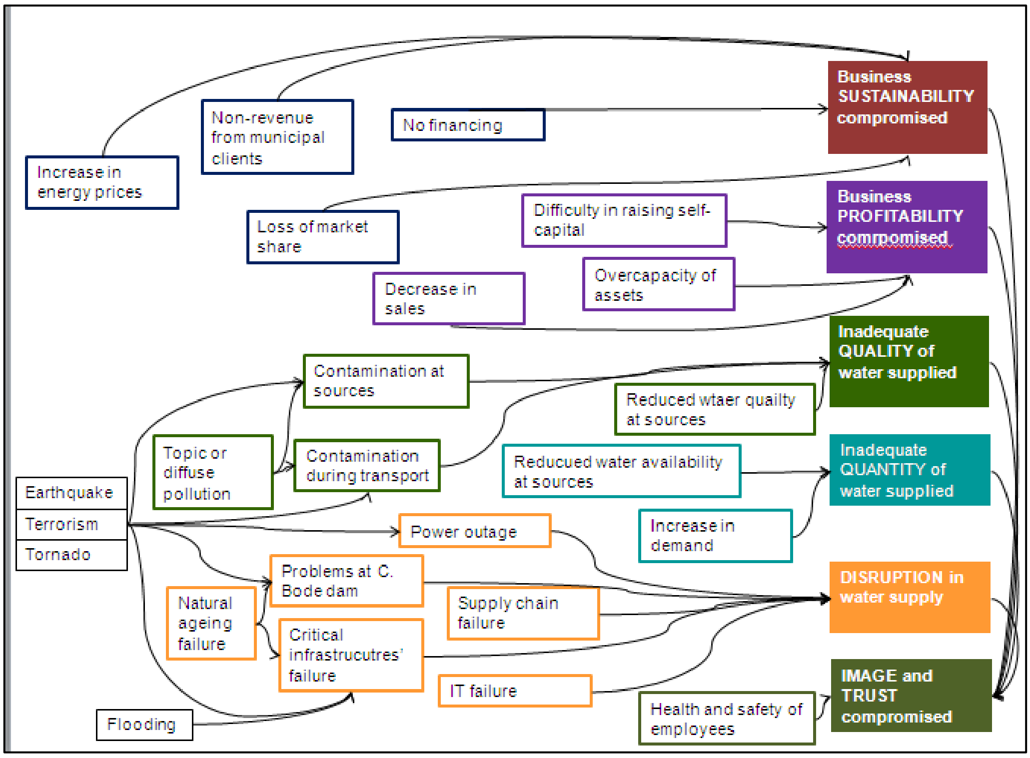
1. Brainstorming in April 2011



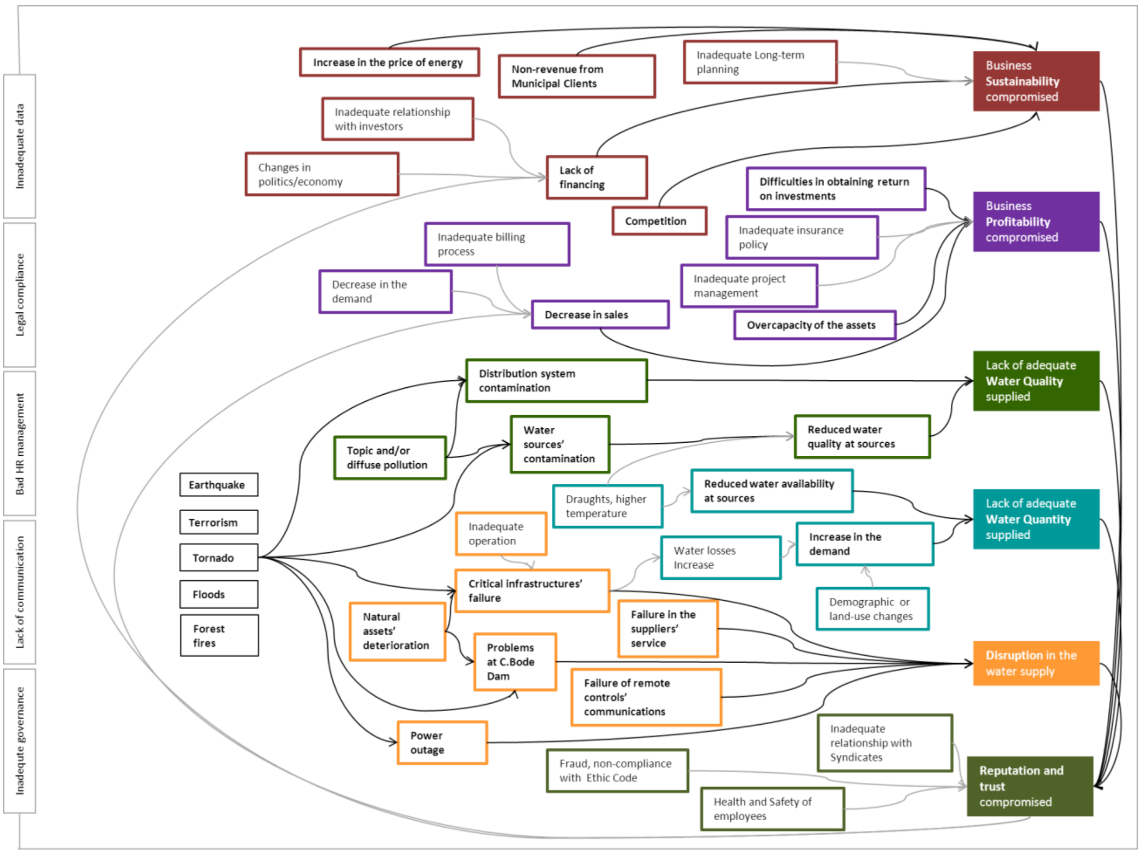
2. Categorizing brainstormed risks

Category	**Risk**	
Quantity	earthquake with dam break	*water unavailability at sources*
Quality	pathogen contamination supply chain failure	catchment contamination *other water sources contamination*
Reliability	Castelo Bode system's failure water supply failure supply chain failure natural hazards (earthquake)	major trunk mains burst distribution mains burst loss of primary asset loss of power supply (outage)
Business Sustainability	non-revenue from municipal clients business (un)sustainability loss of financing	change in governance model loss of competitiveness in bulk supply
Image	non-compliance	

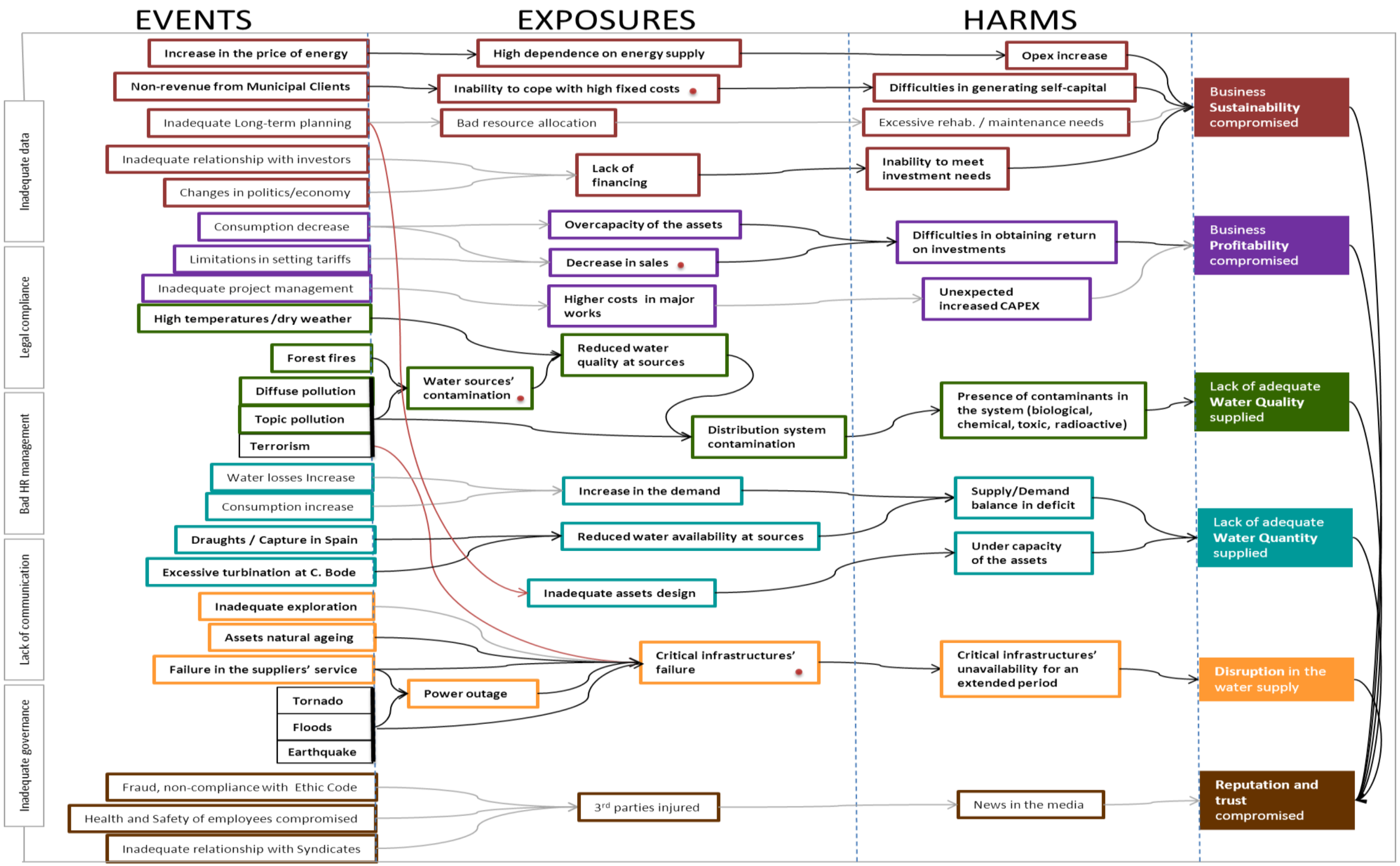
3. Influence diagram (1st version)



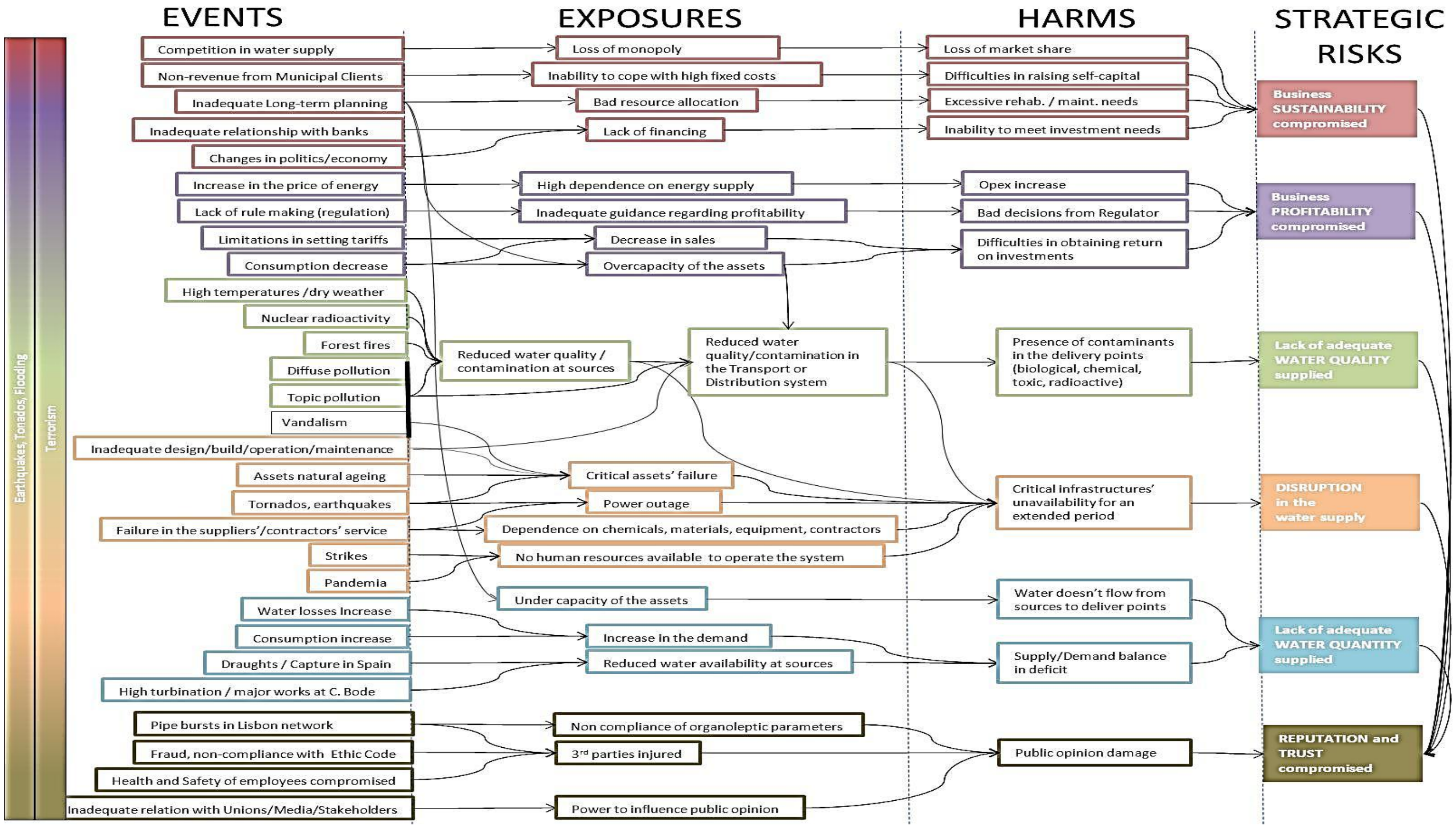
4. Influence diagram (2nd version, after inputs from COSO at EPAL)



5. Influence diagram (3rd version, evidencing events, exposures and harms)



6. Influence diagram (4th version, after discussion with risk experts and risk managers)



Appendix D – Assigning significance to consequences' classes

Class	Strategic risk - consequences	Justification
5 – Catastrophic	The company will not be able to accomplish its mission in the next 10 years	It would take 10 years to shut EPAL down
4 – Very bad	The company will not be able to accomplish its mission in the next 20 years	A salvation plan might be designed
3 – Bad	The company will be able to accomplish its mission in the next 20 years but struggling with high economic or financial constraints	Sustainability is reachable, despite the difficulties
2 – Moderate	The company will be able to accomplish its mission in the next 20 years with moderate economic or financial constraints	Sustainability is guaranteed, despite moderate difficulties
1 - Minor	The company will be able to accomplish its mission in the next 20 years with minor economic or financial constraints	Sustainability is guaranteed
5 – Catastrophic	The company will be in deficit	EPAL has been generating profits for the last decades
4 – Very bad	The company will decrease its profits by more than 75% up to 100%	EPAL would change from a profitable organization to almost in deficit
3 – Bad	The company will decrease its profits by more than 25% and less than 75%	This means a reduction of 10 to 30 million EUR
2 – Moderate	The company will decrease its profits by less than 25%	This means a reduction of around 10 million EUR
1 - Minor	The company will maintain its level of profits	EPAL will keep its profits around 40 million EUR

Class	Strategic risk - consequences	Justification
5 – Catastrophic	50 or more customers will present non-reversible health problems, including the possibility of death	Any death is considered “very bad” of “catastrophic”. Given the scale of the supply system, a major water quality problem will affect more than one customer (if it were only one, it would be difficult to prove the cause was water quality).
4 – Very bad	Less than 50 customers will present non-reversible health problems, including the possibility of death OR more than 5000 thousand customers will present reversible health problems	
3 – Bad	Less than 5000 thousand and more than 500 customers will present reversible health problems	500 to 5000 customers correspond to a local municipal supply.
2 – Moderate	Less than 500 and more than 50 customers will present reversible health problems	50 to 500 customers correspond to direct customers in a DMA.
1 - Minor	Less than 50 customers will present reversible health problems	Up to 50 customers correspond to a building in Lisbon or to direct customers on trunk mains
5 – Catastrophic	50% or more of the daily average flow will not be supplied during 6 months or more	In case water scarcity at sources occurs, EPAL will not cut the supply to some customers, but, instead, will reduce the amount of water supplied.
4 – Very bad	50% or more of the daily average flow will not be supplied during 1-6 months	6 months is the time it takes to implement adaptation measures (e.g. opening new boreholes).
3 – Bad	25%-50% of the daily average flow will not be supplied during 6 months or more	
2 – Moderate	25%-50% of the daily average flow will not be supplied during 1-6 months	1-6 months corresponds to the dry season.
1 - Minor	Less than 25% of the daily average flow will not be supplied during more than 1 month	
5 – Catastrophic	2,0 million or more customers will not be supplied at all during 4 days or more	It corresponds to a major failure in Vila Franca de Xira site.
4 – Very bad	0,1-2,0 million customers will not be supplied at	It corresponds to a failure in Castelo do Bode

Class	Strategic risk - consequences	Justification
	all OR 2,0 million or more customers will be partially supplied during 4 days or more	system upstream Alcanhões.
3 – Bad	0,1 million or less customers will not be supplied at all OR 0,5-2,0 million customers will be partially supplied during 4 days or more	It corresponds to a failure in Costa do Sol sub-system.
2 – Moderate	0,1-0,5 million customers will be partially supplied during 4 days or more	It corresponds to failures in other less critical points in the system.
1 - Minor	0,1 million or less customers will be partially supplied during 4 days or more	It corresponds to failures in other even less critical points in the system.
5 – Catastrophic	One breaking news OR more than one non breaking news per year defaming the quality of the water supplied	Water quality is the major contributor to loss of confidence from customers on drinking water.
4 – Very bad	One breaking news OR more than one non breaking news per year related with 3rd parties or H&S injuries	Employees' injuries or damages caused to 3rd parties negatively affect image, but not as much as water quality.
3 – Bad	One breaking news OR more than one non breaking news per year defaming the reliability of the water supplied	Disruption in supply due to asset failure can be explained by their natural ageing.
2 – Moderate	One breaking news OR more than one non breaking news per year defaming the governance of the company	Defaming news about governance may affect the Board, but does not affect customers' trust on drinking water.
1 - Minor	One breaking news OR more than one non breaking news per year related with the quality of service but where harms cannot be directly imputable to EPAL (due diligence)	Image can be less affected if the causes of failure in the quality of service are not directly imputed to EPAL (e.g.: drought).

Appendix E - Information gathered during the meetings with Risk Experts

No.	Box	Type	Evidences	Notes	Probabilities	Probabilities notes
1	Competition in water supply	Event	Experience with AdO	Municipalities may start producing their own water (in case the price of water gets too high for them, for example).	DRC: 1/10 - 1/100 PCG: 1/10 - 1/100	-
2	Non-revenue from municipal clients	Event	Already happening (Torres Novas)	Municipal clients do not pay their water bills either because they cannot afford them or because they do not want to (litigation).	PCG/DAF: 1/100 - 1/1000 DGA: 1/10 - 1/100 (present economic context) DRC: 1/1 - 1/10 (already happening)	Taking into account the economic and financial situation of Portugal.
3	Inadequate long-term planning	Event		Long-term planning does not anticipate assets' needs or demand evolution, leading to bad resource allocation (maintenance, rehabilitation) or inadequate assets' design (over or under capacity of the assets).	DRC: 1/10 - 1/100 ("til when will the consumption continue decreasing") PCG/DAF: 1/100-1/1000 (part of the existing Master Plan deficiencies is being compensated by a better knowledge of the assets; planning is adjustable) DIR: 1/100000 (for the strategic objective) DGA: 1/10 - 1/100 ("existing Master Plan is being followed, but limitations in the investments may cause problems")	The existing Master Plan may not be perfect ("How far will the decrease in the consumption go?"), but it might be compensated by the increase in the knowledge about the assets that has been occurring. The planning is not rigid, and to a certain extent it can be adjusted in face of reality.

No.	Box	Type	Evidences	Notes	Probabilities	Probabilities notes
4	Inadequate relationship with banks	Event		Due to a bad reputation or to a bad financial health of EPAL, banks do not trust in EPAL's capacity to pay for the loans.	PCG/DAF: 1/10000 - 1/100000 ("EPAL has a very good relationship with EIB")	"EPAL has a very good relationship with EIB".
5	Changes in politics/economy	Event		There is a lack of stability in politics/economy that may adversely impact the financing capacity as well as the operational costs of EPAL. Uncertainty about the future is high.	PCG/DAF: 1/10 - 1/100 JUR: 1/1 - 1/10 ("lack of stability; change in politics imply changes in laws) DGA: 1/1 - 1/10 ("EPAL is a Portuguese company -> reduced trust in the markets") LOG: 1/1 - 1/10 ("local --> global") DIR: 1/1 - 1/10	
6	Loss of monopoly	Exposure			Due to the strength of the barrier (L/M), it inherits P(1 - Competition in water supply (Event))=1/10-1/100	
7	Inability to cope with high fixed costs	Exposure			Due to the strength of the barrier (L), it inherits P(2 - Non-revenue from municipal clients (Event)) =1/10 - 1/1000	

No.	Box	Type	Evidences	Notes	Probabilities	Probabilities notes
8	Bad resource allocation	Exposure		Continuously bad resource allocation, so that sustainability might be compromised.	P = 1/10 - 1/1000 (inherit 3) It happened once and a while in the past and had no effect on business sustainability - Alviela, Lisbon distribution network	
9	Lack of financing	Exposure		There is no financing to EPAL, due either to a bad relationship with banks or to changes in Politics/Economy.	P = 1/1 - 1/10, due to P(5 - Changes in politics/economy (Event))	
10	Loss of market share	Harm			Due to the strength of the barrier (L/M), it inherits P(6 - Loss of monopoly (Exposure))=1/10-1/100	
11	Difficulties in raising self-capital	Harm			Due to the strength of the barrier (L), it inherits P(2 - Non-revenue from municipal clients (Event)) =1/10 - 1/1000	
12	Excessive rehabilitation / maintenance needs	Harm		Assets' condition and performance are such that the amount of CAPEX and OPEX needed for the system to operate is so high that might compromise business sustainability.	P = 1/10 - 1/1000 (not foreseen to happen in the next 18 months) DSO: P = 1/10 - 1/100	

No.	Box	Type	Evidences	Notes	Probabilities	Probabilities notes
13	Inability to meet investment needs (AM best practices)	Harm	PAI 2013-2015	The capacity to invest in new assets or in the renewal of the existing ones is not enough to cope with all the needs.	P = 1/10 - 1/100	
14	Increase in the price of energy	Event	"Relatório e Contas 2011"	Energy is the highest operational cost of the company, and its price has been increasing over the last years.	DAF/PCG: 1/1 - 1/10 DGA: 1/1 - 1/10	
15	Regulation - Lack of rule making	Event		The regulatory model for EPAL is explained by rules and codes that are not sufficient to clarify what is expected from EPAL. Consequently, it is not clear the way how profitability should be evaluated as well as the way tariffs are approved by the regulator.	PCG/DAF: P = 1/1 - 1/10	
16	Limitations in setting tariffs	Event		Tariffs cannot be increased regardless the surplus that may be needed to cope with the fixed costs, due to regulation constraints. It depends upon a political decision.	DGA: 1/1 - 1/10 PCG/DAF: 1/1 - 1/10	

No.	Box	Type	Evidences	Notes	Probabilities	Probabilities notes
17	Consumption decrease	Event		Decrease in consumption of the actual customers, due to either change of practices, economic constraints or to a reduction in their water losses (for municipal or multi-municipal clients)	PCG/DAF: 1/1 - 1/10 DGA: 1/1 - 1/10 DRC: 1/1 - 1/10	
18	High dependence on energy supply	Exposure		The water supply system of EPAL is designed in such a way that energy is needed not only to abstract water from all of the current sources (superficial and underground) but also to deliver it to the customers.	P = P(14 - Increase in the price of energy (Event)) = 1/1 - 1/10	
19	Inadequate guidance regarding profitability	Exposure		The regulatory model for EPAL is explained by rules and codes that are not sufficient to clarify what is expected from EPAL. Consequently, it is not clear the way how profitability should be evaluated as well as the way tariffs are approved by the regulator.	P = P(15 - Regulation - Lack of rulemaking (Event)) = 1/1 - 1/10	
20	Decrease in sales	Exposure		Decrease in sales for the actual clients		

No.	Box	Type	Evidences	Notes	Probabilities	Probabilities notes
21	Overcapacity of the assets	Exposure		Assets had been designed taking into account an estimated level in demand that has proven to be excessive in the present (due to an inadequate planning or to a decrease in the consumption).	P = P(17 - Consumption decrease (Event)) = 1/1 - 1/10	
22	OPEX increase	Harm	"Relatório e Contas 2011"	Operational costs may increase due to the increase on the different parcels that contribute to it, namely external supplies and services (FSE), including energy.	P = 1/1000 - 1/10000 Although all the other costs have a positive trend, costs with personnel have been exceptionally low due to a resolution of the Government; efficiency has been increasing (energy, water losses), but it is not sufficient to cope with the increase in the price of energy, for example.	

No.	Box	Type	Evidences	Notes	Probabilities	Probabilities notes
23	Bad decisions from Regulator	Harm		The regulatory model for EPAL is explained by rules and codes that are not sufficient to clarify what is expected from EPAL. Consequently, it is not clear the way how profitability should be evaluated as well as the way tariffs are approved by the regulator.	P = P(15 - Regulation - Lack of rulemaking (Event)) = 1/1 - 1/10	
24	Difficulties in obtaining return on investments	Harm		Difficulties result from a decrease in sales and from an overcapacity of the assets, which were designed to supply higher levels of demand. It should be noted, though, that ROI is not always easy to be measured.	P = P(16 - Limitations in setting tariffs (Event)) = 1/1 - 1/10	
25	High temperatures / dry weather	Event	Happened in the summer of 2012	The increase in the number of days per year with high temperatures (T>30 ^{0}C) in dry weather may lead to a degradation of water quality in the superficial water sources (considering that pollution loads are as usual for that season).	DGA: 1/1 - 1/10 (history) LAB: 1/1 - 1/10 (history) DIR: 1/1 - 1/10 (2012 history)	It happened last summer in Valada-Tejo.

No.	Box	Type	Evidences	Notes	Probabilities	Probabilities notes
26	Radioactivity (Problems at Almaraz)	Event		Problems at Almaraz - nuclear power plant is located ≈100 km upstream the border Portugal/Spain, on the bank of Tagus river. If an accident occurs, water may be contaminated either by propagation of the nuclear radiation by air or by the river.	LAB: 1/100-1/1000 or 1/1000-1/10000 Note: A study is undergoing to know more about this.	A study is undergoing to find out more about this subject.
27	Forest fires	Event	It usually happens in the summer, around Castelo do Bode reservoir	The land use around C.Bode is mostly comprised by forest areas, many of which usually are set on fire on the summer seasons. If the magnitude and location of the burnt areas are such that ashes get into the reservoir (either via atmosphere or following heavy rain episodes), the raw water quality may be affected by higher turbidity and HAPC (hydro carbonates).	LAB: 1/10 - 1/100 (not severe until now, negative effects have not been experienced; WTP also can deal with HAPC and the intake tower has 3-4 levels of abstraction) DGA: 1/1 - 1/10 (severe)	Until now, severity of the forest fires has been such that did not affect the treatment of water at Asseiceira.

No.	Box	Type	Evidences	Notes	Probabilities	Probabilities notes
28	Diffuse pollution	Event		Diffuse pollution may occur in the watershed upstream the water sources or along the supply system. It may be due to agriculture practices (pesticides, nitrates, phosphates) or to cattle (organic matter, crypto, giardia).	LAB: 1/1 - 1/10 DGA: 1/10 - 1/100	It is detected in raw water.
29	Point source pollution	Event		Point source pollution may occur in the watershed upstream water sources or along the supply system. It may be due to treated or untreated wastewater discharges, to spillage of dangerous substances or to the leaking from landfills or quarries. In the distribution system, it may also be due to contamination during maintenance actions.	LAB: 1/1 - 1/10 (historically, it is due to wastewater; not spills, landfill, quarries or maintenance) DGA: 1/10 - 1/100	Wastewater is the major contribution.
30	Vandalism	Event		An act of vandalism within water supply system that may put in danger asset integrity or the safety of the delivered water quality.	DSO: P=1/1 - 1/10 (high)	It has been occurring in the last years

No.	Box	Type	Evidences	Notes	Probabilities	Probabilities notes
31	Reduced water quality / contamination at sources	Exposure		Water quality at surface or underground sources may decrease due to natural or anthropogenic causes. Contaminants may be biological, chemical, toxic or radioactive.	P = 1/1 - 1/10 (point source or diffuse pollution) at Valada, Ota, Alenquer; P = 1/10 - 1/100 (forest fires) at C.Bode; there is a recent study that shows that Panasqueira mines landfill pose no threat to raw water quality at C.Bode; P = 1/10 - 1/100 (natural radioactivity) at Lezírias	Due to the point source and diffuse pollution that occurs at Valada-Tejo, Ota and Alenquer. A recent study has shown that Panasqueira mines' landfill pose no threat to raw water quality at C.Bode.
32	Reduced water quality / contamination in the Transport or Distribution system	Exposure	Analysis to non-compliances made by LAB in the Transport and Distribution system.	Water quality in the transport or distribution system may decrease due to contamination from the source or directly in the supply system. This latter is especially relevant in Alviela and Tagus aqueducts (free surface flow) and mainly at Alviela (very bad condition; water pressure drains). It may also occur due to an overcapacity of the mains that lead to a decrease in the flow velocity.	P = 1/1 - 1/10 (Tejo - ex.: THM) P = 1/100 - 1/1000 (other trunk mains)	Vale da Pedra WTP is not so robust as Asseiceira WTP, but the mix of waters prove to be effective. Analysis to samples in the Transport or Distribution system indicates that direct contamination is not relevant, although Alviela aqueduct's vulnerability is very high.

No.	Box	Type	Evidences	Notes	Probabilities	Probabilities notes
33	Presence of contaminants in the delivery points (biological, chemical, toxic, radioactive)	Harm		Presence of contaminants in the delivery points in such a way that may affect consumers' health.	LAB: P = 1/1 - 1/10 -> IVPs + THM P = 1/100 - 1/1000 -> large scale	
34	Inadequate AM practices / design / operation / maintenance	Event	"Relatório e Contas 2011"	Inadequate AM practices / design / operation / maintenance due to poorly qualified workers, insufficient supervising or other control measures, financial or time constraints, etc.	DRH: 1/1- 1/10 future DGA: 1/10 - 1/100 DIR: 1/10- 1/100	More than 200 employees are aged 55+ and there is no HR strategic plan. Government rules do not allow the recruitment of new people.
35	Assets natural ageing	Event	Pamraj Patil's thesis	EPAL's water supply system is comprised by recent sub-systems (ex.: C.Bode, Circunvalação, V.F.Xira-Telheiras, significant part of Distribution network) but also by old systems (Alviela, Tejo, part of Distribution network). The likelihood of failure of the latter is getting higher, although these are not the most critical infrastructures (with exception to V.Pedra WTP, which will soon be refurbished).	DIR: 1/100 - 1/1000 (C.Bode, …) DGA: 1/10 - 1/100 (Tejo, V.Pedra)	MSc thesis "Forecasting the failure probability for water mains" (Padmraj Patil) evidences that failures in trunk mains will occur within the next 100 years.

No.	Box	Type	Evidences	Notes	Probabilities	Probabilities notes
36	Tornados, floods, earthquakes	Event		Natural catastrophes such as tornados, floods and earthquakes may destroy assets, contaminate water and/or affect power production and distribution.	DSO: 1/10 - 1/100 ("a major natural catastrophe is due to happen in 50 years") DGA: 1/10 - 1/100 DIR: 1/10 - 1/100 ("1/50")	"Mini-tornados have been occurring in recent years".
37	Failure in the suppliers' / contractors' / service	Event		Suppliers/contractors fail to meet agreed service due to economic, social or other reasons.	DIR: 1/1 - 1/10 (ex.: contractor's bankruptcy) LOG: 1/1 - 1/10 ("there is no stock"; since 10 years ago: local->global; terrorism, political changes, economic; high dependence on one supplier (IS, SCADA, energy, valves) DGA: 1/100 - 1/1000 ("nowadays, the process is controlled and stable)"	EPAL has already experienced contractor's bankruptcy, due to the actual economic crisis. For some of the products, there is no stock. In some cases there is a high dependence on one supplier. The process is controlled and stable, but there is a need to improve the process of evaluating the suppliers.

No.	Box	Type	Evidences	Notes	Probabilities	Probabilities notes
38	Strikes	Event		Occurrence of strikes in EPAL.	DRH: 1/1- 1/10 (it has been happening over the years) DGA: 1/10 - 1/100 PCG: 1/10- 1/100	It has occurred in the last years and the economic and financial crisis tend to increase the frequency of strikes.
39	Pandemic	Event				
40	Critical assets' failure	Exposure		Failure of the assets due to mechanical, electrical or structural problems.	DGA: 1/10 - 1/100 (ex.: C.Bode-> even with AM best practices barrier, it may not be as robust as that, depends on political decision)	

No.	Box	Type	Evidences	Notes	Probabilities	Probabilities notes
41	Power outage	Exposure		Power outage may be caused by internal problems in the power supply system or be due to natural catastrophes.	P = P(36 - Tornados, floods, earthquakes (Event)) = 1/10 - 1/100	"A major natural catastrophe is due to happen in 50 years".
42	Dependence on supply of chemicals, materials, equipment, services	Exposure		The system functionality is highly dependent on the supply of chemicals, materials, equipment and, in some cases, outsourced work force.	P = 1/1 (especially in the case of electricity)	
43	Insufficient human resources to operate the system	Exposure		Unavailability of human resources in such a way that water supply system cannot be operated, due to social problems (demonstrations, strikes, etc.) or to pandemic.	P = 1/1000 - 1/100000 (because of the strength of the barrier, which is due to a high level of consciousness) or P = 1/10 - 1/100 (because social tension is increasing)	Social tension is high, but awareness of EPAL's mission is also high.
44	Critical infrastructures' unavailability for an extended period	Harm		Critical assets unavailability for an extended period, due to mechanical, electrical or structural failure, to lack of chemicals to treat water, to lack of people to operate the system, to a power outage or to the presence of contaminated water in the system.	P = 1/10 - 1/100 (from natural disasters + assets ageing)	

No.	Box	Type	Evidences	Notes	Probabilities	Probabilities notes
45	Water losses increase	Event		Water losses (either in EPAL's system or in the distribution systems of the Municipal Clients) may increase due to ageing of the mains and to insufficient maintenance or renewal practices.	DGA: P = 1/10000 - 1/100000 (data show that it is happening the opposite)	
46	Consumption increase	Event		Consumption may increase due to an increase in population or in economic activity	All: P = 1/10000 - 1/100000 (data show that the opposite is happening)	
47	Droughts / Capture in Spain	Event	Adaptaclima	Occurrence of severe or extreme droughts, which may lead to retention of water in the Spanish basin of Tagus River	DGA: P = 1/10 - 1/100(there is no evidence that it might happen until next year; C.Bode proved to be resilient in 2005)	Adaptaclima project foresees that extreme droughts will occur within the next 20 years, but C. Bode reservoir is very resilient and it will not happen during this hydrological year.

No.	Box	Type	Evidences	Notes	Probabilities	Probabilities notes
48	High turbination or major works at C.Bode	Event		C.Bode reservoir is shared with EDP that uses it for electricity production. If the turbination lowers the water level below EPAL's intakes, EPAL will not be able to abstract water from that source.	DGA: P = 1/100 - 1/1000 (presently, there is a contract that establishes the minimum level below which the hydropower plant cannot operate; EDP's awareness of the importance of complying with that is very high; no major works in the dam (that might lead to the emptying of the reservoir) are foreseen (source: EDP).	It is safeguarded in EDP's concession contract with APA that they cannot turbinate below a level that compromises EPAL.
50	Increase in the demand	Exposure		Increase in the demand (by actual clients) result from an effective increase in consumption and/or an increase in water losses.	All: P = P(46 - Consumption increase (Event)) = 1/10000 - 1/100000	

No.	Box	Type	Evidences	Notes	Probabilities	Probabilities notes
51	Reduced water availability at sources	Exposure		Water availability at sources is reduced due to the occurrence of droughts or, for C.Bode, problems at the dam/high turbination.	P = P(48 - High turbination or major works at C.Bode (Event)) = 1/100 - 1/1000, since C.Bode represents approximately 70% of the sources and is located in the most upstream of the system (this allowing to cover for any needs downstream)	Adaptaclima project foresees that extreme droughts will occur within the next 20 years, but C. Bode reservoir is very resilient and it will not happen during this hydrological year. It is safeguarded in EDP's concession contract with APA that they cannot turbinate below a level that compromises EPAL.
49	Under capacity of the assets	Exposure		Assets are under designed for the actual demand	P = 1/1000 - 1/10000 (the opposite is happening)	
52	Water doesn't flow from sources to the delivery points	Harm		Assets are functioning but are not able to deliver the total demanded flow because of their under capacity.	P = 1/10000 - 1/100000	

No.	Box	Type	Evidences	Notes	Probabilities	Probabilities notes
53	Supply/Demand balance in deficit	Harm		The demand for water exceeds the availability at sources.	P = P(50 - Increase in the demand (Exposure)) = 1/10000 - 1/100000, (since demand is decreasing, there is a kind of compensation for a potential effect of droughts)	
54	Pipe bursts in Lisbon network *(abbrev.)*	Event		Pipe bursts occur every week in the distribution system. This can cause "brown water" to flow from taps (after the repair) and, in some cases, damages to private properties. Organoleptic issues may also arise from the operational conditions (low flow velocities).	P = 1/1 - 1/10	

No.	Box	Type	Evidences	Notes	Probabilities	Probabilities notes
55	Fraud, non-compliance with Ethic Code	Event		Fraud or other actions that do not comply with EPAL's ethic code.	LOG: P = {1,2} (there is still a lot to improve: "preference, dependencies, …"; the suppliers evaluation procedure can be improved (and more evident) JUR: P = 1/100 - 1/1000 ("Public Contracting Code" is much more restrictive; there is no track of problems) DGA: P = 1/100 - 1/1000 (Problems reported by LOG are real specially regarding procedure optimization - they have no strategic impact; bad classification of suppliers, or lack of willing for improvement.	The mechanisms to avoid non-compliances with Ethic Code exist.
56	Health and Safety of employees compromised	Event	"Relatório e Contas 2011"	Employees may be seriously injured (or killed) during their working activities.	DRH: 1/10 - 1/100 (due to a lack of knowledge transfer) DGA: 1/10- 1/100 (risk related to interventions in power stations, DGA is aware and alert)	

No.	Box	Type	Evidences	Notes	Probabilities	Probabilities notes
57	Inadequate relationship with Unions / Media / Stakeholders	Event		An inadequate relationship with Unions / Media / Stakeholders may lead to an increase in the release of defaming news.	DGA: 1/1 - 1/10 (historically, although it has improved a lot -> next year: 1/10 - 1/100)	It has happened in the past.
58	Noncompliance of organoleptic parameters	Exposure		Organoleptic parameters (colour, smell, taste) may be beyond the required level.	P = 1/1 - 1/10 or 1/10 - 1/100	Number of claims is low.
59	3rd parties injured	Exposure		3rd parties may be injured due to the occurrence of pipe bursts, non-compliance with ethical code or health and safety failure.	P = P(55 - Fraud, non-compliance with Ethic Code (Event)) = P(56 - Health and Safety of employees compromised (Event)) = 1/10 - 1/100 (Pipe burst occur every week but the 'big ones' do not occur so often)	Mainly due to pipe bursts in Lisbon.
60	Negative influence on public opinion	Exposure		Unions, media and stakeholders have the power to influence public opinion, through the release of defaming news.	P = P(57 - Inadequate relationship with Unions / Media / Stakeholders (Event)) = 1/10 - 1/100	

No.	Box	Type	Evidences	Notes	Probabilities	Probabilities notes
61	Public opinion damage	Harm		Damage in public opinion may arise from "direct causes" (non-compliance with organoleptic parameters, 3rd parties injured, inadequate relationship with syndicates and media) or "indirect causes" (failure to achieve each of the other strategic objectives).	P = 1/10 - 1/100 (direct causes -> syndicates)	The range is due to the contribution of both "direct" and "indirect causes".
100	Inadequate governance	Risk factor		Inadequate governance may be due to an excessive interference of the Government in EPAL's management. It has effects on the image (identification of EPAL with the image of the public sector in general), on the approval of investments, on the salaries and EPAL's capacity to capture talent, etc. (Profitability), etc.	P = 1/1 - 1/10	

No.	Box	Type	Evidences	Notes	Probabilities	Probabilities notes
101	Lack of communication	Risk factor		Lack of communication between people (especially from different departments) may lead to several inefficiencies in the processes. It affects profitability (non-optimized working processes) and may affect the disruption in the supply or the health and safety of employees.	DGA: 1/1 - 1/10	
102	Poor HR practices	Risk factor		Poor HR practices result from difficulties in capturing talent to the company; in ensuring that knowledge transfer is made when employees get retired or move to another company; and also in renewing "minds" in the company ("familiar dynasties"). This directly affects AM practices. NOTE: >200 / 700 employees are aged 55+	DRH: 1/1 - 1/10 ("there is no HR strategic plan to retain/capture kwon-how, including on-job training") DIR: 1/1 - 1/10 (no procedures) DGA: 1/1 - 1/10 (no knowledge transfer; no new admissions)	

No.	Box	Type	Evidences	Notes	Probabilities	Probabilities notes
103	Legal non-compliance	Risk factor		Non-compliance with current legislation. It affects reputation and trust.	JUR: 1/100 - 1/1000 - There are mechanisms of control set up. - Noncompliance may occur either because laws change too often (and control mechanisms fail) or because we decide to (ex. monthly billing). - There is a lack of stability that does not allow proper long or mid-term planning to be done.	
104	Inadequate data/information	Risk factor		Inadequate data or information about the different subjects of the company - namely the assets - leads to an increase in the inefficiency of the processes and to bad decision-making (affects Profitability).	DGA: 1/1 - 1/10 (ex. MAXIMO) DIR: 1/1 - 1/10 (ex. MAXIMO)	

Appendix F – Validation workshop: materials provided and other arrangements

1. ARRANGEMENTS

Workshop: Strategic Risk Management
Venue: Hotel Plaza

	Tuesday 22-01-2013	**Wednesday** 23-01-2013
09h15-09h50	Presentation of the participants *(All)*	BUILDING FUTURES' SCENARIOS (cont.) - key-drivers presentation and validation *(Fiona Lickorish + specialists + Working groups)*
09h50-10h00	Framework and objectives *(Simon Pollard)*	
10h00-11h00	RISK ASSESSMENT (IN THE PRESENT) Presentation of the main conclusions from the meetings with risk experts *(Ana Luis)*	
11h00-11h20	*Coffe-Break*	*Coffe-Break*
11h20-13h15	- Discussion of the results and presentation of the conclusions *(Working groups)*	- Analysis of the key-drivers and respective connections *(Fiona Lickorish + specialists + Working groups)*
13h15-14h30	*Break (lunch not included)*	*Break (lunch not included)*
14h30-16h00	BUILDING FUTURES' SCENARIOS - Introduction (Fiona Lickorish)	- Analysis of the key-drivers and respective connections *(Fiona Lickorish + specialists + Working groups)*
16h00-16h20	*Coffe-Break*	*Coffe-Break*
16h20-18h00	- Presentation of exisitng methodologies *(Fiona Lickorish)*	- Analysis of the key-drivers and respective connections *(Fiona Lickorish + specialists + Working groups)*
18h00-18h15	*Closing remarks*	*Closing remarks*

NOTE: Working group discussions will be supported and oriented by Prof. Simon Pollard and other specialists.

2. PARTICIPANTS

Risk Managers	Risk Experts
Joaquim José Nunes Sereno <jsereno@epal.pt>	Nuno Medeiros
	José Salgueiro
Luis Manuel de Lemos Branco <luisbran@epal.pt>	Helena Silva
	Diana Constant
	Cláudia André
Francisco F.S. Serranito <fserrani@epal.pt>	Maria João Capela
	Francisco Braga
	Nuno Reis
José Fernando Crisóstomo Figueira <JoseFigueira@epal.pt>	Marco Santos
	Helena Saraiva
Mário Jorge Santos Maria <mariom@epal.pt>	Sérgio Rodrigues
	Guilherme Hora
Maria João Araujo Gouveia Benoliel <mjbenol@epal.pt>	Rui Neves Carneiro
	Sofia Damião
Anita Lourenço Bento Ferreira <aferreir@epal.pt>	Joaquim Broes
Barnabé Pisco <barnabep@epal.pt>	Alberto Martins
Marcos Miguel	António Matos
Conceição Almeida <conceal@epal.pt>	Ana Amélia
	Ricardo Silva
Paulo Marco C. Rodrigues <paulord@epal.pt>	Carlos Gonçalves
José Manuel Oliveira Zenha <Jose.Zenha@epal.pt>	-----
Bruno Cortes Lopes <blopes@epal.pt>	Bruno Lopes
Carlos Saraiva	Ivo Joaquim
	Paula Serrinha

3. WORKING GROUPS – DAY #1

SUSTAINABILITY	PROFITABILITY
Anita Ferreira	António Matos
Joaquim Broes	Luis Branco
Paula Rodrigues	Cláudia André
Marcos Miguel	Bruno Lopes
Francisco Braga	Maria João Capela

REPUTATION	
José Zenha	Helena Silva
Helena Saraiva	Carlos saraiva
Diana Constant	Ivo Joaquim
Barnabé Pisco	Carlos Gonçalves

QUALITY	
Maria João Benoliel	Luis Bucha
Rui Neves Carneiro	Sérgio Rodrigues
Sofia Damião	Alberto Martins
Marco Santos	Ana Amélia

QUANTITY	
Mário Maria	Marcos Sá
Guilherme Hora	João Mugeiro
Francisco Serranito	C. Vieira Gomes
Andrew Donnelly	Ricardo Silva

RELIABILITY	
Joaquim Sereno	Conceição Almeida
Nuno Medeiros	Paula Serrinha
José Salgueiro	José Figueira
Paulo Rodrigues	Nuno Reis

4. WORKING GROUPS – DAY #2

Group A Economic/Social	Group B Political/Technology	Group C Legal/Environment
Nuno Medeiros	José Salgueiro	Diana Constant
Cláudia André	Maria João Capela	Marco Santos
Joaquim Broes	Francisco Braga	Helena Saraiva
António Matos	Nuno Reis	Sérgio Rodrigues
Ana Amélia	Ricardon Silva	Guilherme Hora
Ivo Joaquim	Carlos Gonçalves	Sofia Damião
Craig Mauelshagen	Simon Pollard	Paula Serrinha
Simon Jude	Ana Luis	Keith Weatherhead
Maria Helena Silva	Nuno Ferreira	Nuno Grosso
Facilitator	**Facilitator**	**Facilitator**
João Delgado	George Prpich	Fiona Lickorish

5. INFLUENCE DIAGRAM (A1 FORMAT) COLOURED ACCORDING TO LIKELIHOOD OF EVENTS, EXPOSURES AND RISKS

Not suitable to be shown here, due to its size. It is similar to Figure 6-5 in the main document, but without a full characterization of the existing barriers. Each group was given one A1 sheet.

6. EVENTS, EXPOSURES AND HARMS' RECORDS

<table>
<tr><td rowspan="6">1</td><td colspan="2">Competition in water supply
Event</td></tr>
<tr><td colspan="2">Municipalities may start producing their own water (in case the price of water gets too high for them, for example).</td></tr>
<tr><td>Influenced by:
n/a</td><td>with the following barriers:
n/a</td></tr>
<tr><td colspan="2">Probability class: Moderate (1/100 - 1/10)
-</td></tr>
<tr><td>Impact on:
6 - Loss of monopoly (Exposure)</td><td>with the following barriers:
- Contractual safeguards (______) --> 6
- Competitive advantadges (_____) --> 6</td></tr>
<tr><td colspan="2">Related with the following strategic risk(s):
Business Sustainability compromised</td></tr>
</table>

2	**Non-revenue from municipal clients** *Event*	
	Municipal clients do not pay their water bills either because they cannot afford them or because they do not want to (litigation).	
	Influenced by: n/a	with the following barriers: n/a
	Probability class: **Moderate to High (1/100 -1/1)** Taking into account the economic and financial situation of Portugal.	
	Impact on: 7 - Inability to cope with high fixed costs (Exposure)	with the following barriers: - Other markets (_____) --> 7
	Related with the following strategic risk(s): Business Sustainability compromised	

3	**Inadequate long-term planning** *Event*	
	Long-term planning does not anticipate assets' needs or demand evolution, leading to bad resource allocation (maintenance, rehabilitation) or inadequate assets' design (over or undercapacity of the assets).	
	Influenced by: n/a	with the following barriers: n/a
	Probability class: **Moderate to High (1/100 -1/1)** The existing Master Plan may not be perfect ("How far will the decrease in the consumption go?"), but it might be compensated by the increase in the knowledge about the assets that has been occurring. The planning is not rigid, and to a certain extent it can be adjusted in face of reality.	
	Impact on: 8 - Bad resource allocation (Exposure) 20 - Decrease in sales (Exposure) 49 - Undercapacity of the assets (Exposure)	with the following barriers: - Periodic review (_____) --> 8, 20, 49
	Related with the following strategic risk(s): Business Sustainability compromised	

<table>
<tr><td rowspan="7">4</td><td>Inadequate relationship with banks
Event</td></tr>
<tr><td>Due to a bad reputation or to a bad financial health of EPAL, banks do not trust EPAL's capacity to pay the loans.</td></tr>
<tr><td>Influenced by:
n/a
with the following barriers:
n/a</td></tr>
<tr><td>Probability class: Very Low to Low (1/10000 - 1/100)
"EPAL has a very good relationship with EIB".</td></tr>
<tr><td>Impact on:
9 - Lack of financing (Exposure)
with the following barriers:
- Build trusty relations (_____) --> 9
- Diverse banks (_____) --> 9</td></tr>
<tr><td>Related with the following strategic risk(s):
Business Sustainability compromised</td></tr>
</table>

<table>
<tr><td rowspan="7">5</td><td>Changes in politics/economy
Event</td></tr>
<tr><td>There is a lack of stability in politics/economy that may adversly impact the financing capacity as well as the operational costs of EPAL. Uncertainty about future is high.</td></tr>
<tr><td>Influenced by:
n/a
with the following barriers:
n/a</td></tr>
<tr><td>Probability class: Certain (1/1)</td></tr>
<tr><td>Impact on:
9 - Lack of financing (Exposure)
with the following barriers:
- Anticipate changes (_____) --> 9</td></tr>
<tr><td>Related with the following strategic risk(s):
Business Sustainability compromised</td></tr>
</table>

6	**Loss of monopoly** *Exposure*	
	Influenced by: 1 - Competition in water supply (Event)	with the following barriers: - Contractual safeguards (_____) --> 6 - Competitive advantadges (____) --> 6
	Probability class: **Moderate (1/100 - 1/10)**	
	Impact on: 10 - Loss of market share (Harm)	with the following barriers: -
	Related with the following strategic risk(s): Business Sustainability compromised	

7	**Inability to cope with high fixed costs** *Exposure*	
	Influenced by: 2 - Non-revenue from municipal clients (Event)	with the following barriers: - Other markets (_____) --> 7
	Probability class: **Moderate to High (1/100 -1/1)**	
	Impact on: 11 - Difficulties in raising self-capital (Harm)	with the following barriers: -
	Related with the following strategic risk(s): Business Sustainability compromised	

8	**Bad resource allocation** *Exposure*	
	Continuosly bad resource allocation, so that sustainability might be compromised.	
	Influenced by: 3 - Inadequate long-term planning (Event)	with the following barriers: - Periodic review (_____) --> 8, 20, 49
	Probability class: **Moderate (1/100 - 1/10)**	
	Impact on: 12 - Excessive rehabilitation / maintenance needs (Harm)	with the following barriers: -
	Related with the following strategic risk(s): Business Sustainability compromised	

9	**Lack of financing** *Exposure*	
	There is no financing to EPAL, due either to a bad relationship with banks or to changes in Politics/Economy.	
	Influenced by: 4 - Inadequate relationship with banks (Event) 5 - Changes in politics/economy (Event)	with the following barriers: - Build trusty relations (_____) --> 9 - Diverse banks (_____) --> 9 - Anticipate changes (_____) --> 9
	Probability class: **Certain (1/1)**	
	Impact on: 13 - Inability to meet investment needs (AM best practices) (Harm)	with the following barriers: - Use cash flow (self-financing) (_____) --> 13 - Retained earnings (_____) --> 13
	Related with the following strategic risk(s): Business Sustainability compromised	

10	**Loss of market share** *Harm*	
	Influenced by: 6 - Loss of monopoly (Exposure)	with the following barriers: -
	Probability class: **Moderate (1/100 - 1/10)**	
	Impact on: (strategic objective)	with the following barriers: -
	Related with the following strategic risk(s): Business Sustainability compromised	

11	**Difficulties in raising self-capital** *Harm*	
	Influenced by: 7 - Inability to cope with high fixed costs (Exposure)	with the following barriers: -
	Probability class: **Moderate to High (1/100 -1/1)**	
	Impact on: (strategic objective)	with the following barriers: -
	Related with the following strategic risk(s): Business Sustainability compromised	

12	**Excessive rehabilitation / maintenance needs** *Harm*	
	Assets' condition and performance are such that the ammount of CAPEX and OPEX needed for the system to operate are so high that might compromise business sustainability.	
	Influenced by: 8 - Bad resource allocation (Exposure)	with the following barriers: -
	Probability class: **Moderate (1/100 - 1/10)**	
	Impact on: (strategic objective)	with the following barriers: -
	Related with the following strategic risk(s): Business Sustainability compromised	

<table>
<tr><td rowspan="7">13</td><td colspan="2">Inability to meet investment needs (AM best practices)
Harm</td></tr>
<tr><td colspan="2">The capacity to invest in new assets or in the renewal of the existing ones is not enough to cope with all the needs.</td></tr>
<tr><td>Influenced by:
9 - Lack of financing (Exposure)</td><td>with the following barriers:
- Use cash flow (self-financing) (_____) --> 13
- Retained earnings (_____) --> 13</td></tr>
<tr><td colspan="2">Probability class: Moderate to High (1/100 -1/1)</td></tr>
<tr><td>Impact on:
(strategic objective)</td><td>with the following barriers:
-</td></tr>
<tr><td colspan="2">Related with the following strategic risk(s):
Business Sustainability compromised</td></tr>
</table>

<table>
<tr><td rowspan="7">14</td><td colspan="2">Increase in the price of energy
Event</td></tr>
<tr><td colspan="2">Energy is the highest operational cost of the company, and its price has been increasing over the last years.</td></tr>
<tr><td>Influenced by:
n/a</td><td>with the following barriers:
n/a</td></tr>
<tr><td colspan="2">Probability class: Certain (1/1)</td></tr>
<tr><td>Impact on:
18 - High dependence on energy supply (Exposure)</td><td>with the following barriers:
-</td></tr>
<tr><td colspan="2">Related with the following strategic risk(s):
Business Profitability compromised</td></tr>
</table>

<table>
<tr><td rowspan="7">15</td><td colspan="2">Regulation - Lack of rule making
Event</td></tr>
<tr><td colspan="2">The regulatory model for EPAL is explained by rules and codes that are not sufficient to clarify what is expected from EPAL. Consequently, it is not clear the way how profitability should be evaluated as well as the way tariffs are approved by the regulator.</td></tr>
<tr><td>Influenced by:
n/a</td><td>with the following barriers:
n/a</td></tr>
<tr><td colspan="2">Probability class: Certain (1/1)</td></tr>
<tr><td>Impact on:
19 - Inadequate guidance regarding profitability (Exposure)</td><td>with the following barriers:
- Discuss models with Regulator (_____) --> 19</td></tr>
<tr><td colspan="2">Related with the following strategic risk(s):
Business Profitability compromised</td></tr>
</table>

<table>
<tr><td rowspan="7">16</td><td colspan="2">Limitations in setting tariffs
Event</td></tr>
<tr><td colspan="2">Tariffs cannot be increased regardless the surplus that may be needed to cope with the fixed costs, due to regulation constraints. It depends upon a political decision.</td></tr>
<tr><td>Influenced by:
n/a</td><td>with the following barriers:
n/a</td></tr>
<tr><td colspan="2">Probability class: Certain (1/1)</td></tr>
<tr><td>Impact on:
20 - Decrease in sales (Exposure)</td><td>with the following barriers:
- Lobbying (_____) --> 20</td></tr>
<tr><td colspan="2">Related with the following strategic risk(s):
Business Profitability compromised</td></tr>
</table>

<table>
<tr><td rowspan="6">17</td><td colspan="2">Consumption decrease
Event</td></tr>
<tr><td colspan="2">Decrease in consumption of the actual customers, due to either change of practices, economic constraints or to a reduction in their water losses (for municipal or multimunicipal clients).</td></tr>
<tr><td>Influenced by:
n/a</td><td>with the following barriers:
n/a</td></tr>
<tr><td colspan="2">Probability class: Certain (1/1)</td></tr>
<tr><td>Impact on:
21 - Overcapacity of the assets (Exposure)
22 - OPEX increase (Harm)</td><td>with the following barriers:
- New clients (_____) --> 21, 22
- Increase market share (_____) --> 21, 22
- Contractual safeguards (_____) --> 22</td></tr>
<tr><td colspan="2">Related with the following strategic risk(s):
Business Profitability compromised</td></tr>
</table>

<table>
<tr><td rowspan="6">18</td><td colspan="2">High dependence on energy supply
Exposure</td></tr>
<tr><td colspan="2">The water supply system of EPAL is designed in such a way that energy is needed not only to abstract water from all of the current sources (superficial and urderground) but also to deliver it to the customers.</td></tr>
<tr><td>Influenced by:
14 - Increase in the price of energy (Event)</td><td>with the following barriers:
-</td></tr>
<tr><td colspan="2">Probability class: Certain (1/1)</td></tr>
<tr><td>Impact on:
22 - OPEX increase (Harm)</td><td>with the following barriers:
- Increase efficiency (_____) --> 22</td></tr>
<tr><td colspan="2">Related with the following strategic risk(s):
Business Profitability compromised</td></tr>
</table>

<table>
<tr><td rowspan="6">19</td><td colspan="2">Inadequate guidance regarding profitability
Exposure</td></tr>
<tr><td colspan="2">The regulatory model for EPAL is explained by rules and codes that are not sufficient to clarify what is expected from EPAL. Consequently, it is not clear the way how profitability should be evaluated as well as the way tariffs are approved by the regulator.</td></tr>
<tr><td>Influenced by:
15 - Regulation - Lack of rule making (Event)</td><td>with the following barriers:
- Discuss models with Regulator (_____) --> 19</td></tr>
<tr><td colspan="2">Probability class: High (1/10 - 1/1)</td></tr>
<tr><td>Impact on:
23 - Bad decisions from Regulator (Harm)</td><td>with the following barriers:
- Shared goals with regulator (_____) --> 23</td></tr>
<tr><td colspan="2">Related with the following strategic risk(s):
Business Profitability compromised</td></tr>
</table>

<table>
<tr><td rowspan="6">20</td><td colspan="2">Decrease in sales
Exposure</td></tr>
<tr><td colspan="2">Decrease in sales for the actual clients.</td></tr>
<tr><td>Influenced by:
15 - Regulation - Lack of rule making (Event)
16 - Limitations in setting tariffs (Event)</td><td>with the following barriers:
- Discuss models with Regulator (_____) --> 19</td></tr>
<tr><td colspan="2">Probability class: High to Certain (1/10 - 1/1)</td></tr>
<tr><td>Impact on:
23 - Bad decisions from Regulator (Harm)</td><td>with the following barriers:
-</td></tr>
<tr><td colspan="2">Related with the following strategic risk(s):
Business Profitability compromised</td></tr>
</table>

<table>
<tr><td rowspan="6">21</td><td colspan="2">Overcapacity of the assets
Exposure</td></tr>
<tr><td colspan="2">Assets had been designed taking into account an estimated level in demand that has proven to be excessive in the present (due to an inadequate planning or to a decrease in the consumption).</td></tr>
<tr><td>Influenced by:
3 - Inadequate long-term planning (Event)
17 - Consumption decrease (Event)</td><td>with the following barriers:
- New clients (_____) --> 21, 22
- Increase market share (_____) --> 21, 22
- Periodic review (_____) --> 9, 21, 52</td></tr>
<tr><td colspan="2">Probability class: Certain (1/1)</td></tr>
<tr><td>Impact on:
25 - High temperatures / dry weather (Event)</td><td>with the following barriers:
- AM best practices (_____) --> 25</td></tr>
<tr><td colspan="2">Related with the following strategic risk(s):
Business Profitability compromised</td></tr>
</table>

<table>
<tr><td rowspan="6">22</td><td colspan="2">OPEX increase
Harm</td></tr>
<tr><td colspan="2">Operational costs may increase due to the increase on the different parcels that contribute to it, namely external supplies and services (FSE), including energy.</td></tr>
<tr><td>Influenced by:
18 - High dependence on energy supply (Exposure)</td><td>with the following barriers:
- Increase efficiency (_____) --> 22</td></tr>
<tr><td colspan="2">Probability class: High (1/10 - 1/1)</td></tr>
<tr><td>Impact on:
(strategic objective)</td><td>with the following barriers:
- Innovation
- Increase overall efficiency
- Other markets</td></tr>
<tr><td colspan="2">Related with the following strategic risk(s):
Business Profitability compromised</td></tr>
</table>

<table>
<tr><td rowspan="6">23</td><td colspan="2">Bad decisions from Regulator
Harm</td></tr>
<tr><td colspan="2">The regulatory model for EPAL is explained by rules and codes that are not sufficient to clarify what is expected from EPAL. Consequently, it is not clear the way how profitability should be evaluated as well as the way tariffs are approved by the regulator.</td></tr>
<tr><td>Influenced by:
19 - Inadequate guidance regarding profitability (Exposure)</td><td>with the following barriers:
- Shared goals with regulator (_____) --> 23</td></tr>
<tr><td colspan="2">Probability class: Moderate to High (1/100 -1/1)</td></tr>
<tr><td>Impact on:
(strategic objective)</td><td>with the following barriers:
- Other markets</td></tr>
<tr><td colspan="2">Related with the following strategic risk(s):
Business Profitability compromised</td></tr>
</table>

<table>
<tr><td rowspan="6">24</td><td colspan="2">Difficulties in obtaining return on investments
Harm</td></tr>
<tr><td colspan="2">Difficulties result from a decrease in sales and from an overcapacity of the assets, that were designed to supply higher levels of demand. It should be noted, though, that ROI is not always easy to be measured.</td></tr>
<tr><td>Influenced by:
21 - Overcapacity of the assets (Exposure)
20 - Decrease in sales (Exposure)</td><td>with the following barriers:
-</td></tr>
<tr><td colspan="2">Probability class: Certain (1/1)</td></tr>
<tr><td>Impact on:
(strategic objective)</td><td>with the following barriers:
- Other markets</td></tr>
<tr><td colspan="2">Related with the following strategic risk(s):
Business Profitability compromised</td></tr>
</table>

<table>
<tr><td rowspan="6">25</td><td colspan="2">High temperatures / dry weather
Event</td></tr>
<tr><td colspan="2">The increase in the number of days per year with high temperatures (T>30 ºC) in dry weather may lead to a degradation of water quality in the superficial water sources (considering that pollution loads are as usual for that season).</td></tr>
<tr><td>Influenced by:
n/a</td><td>with the following barriers:
n/a</td></tr>
<tr><td colspan="2">Probability class: Certain (1/1)
It happened last summer in Valada-Tejo.</td></tr>
<tr><td>Impact on:
31 - Reduced water quality / contamination at sources (Exposure)</td><td>with the following barriers:
- Stakeholders engagement (_____) --> 31</td></tr>
<tr><td colspan="2">Related with the following strategic risk(s):
Lack of adequate Water Quality supplied</td></tr>
</table>

<table>
<tr><td rowspan="6">26</td><td colspan="2">Radioactivity (Problems at Almaraz)
Event</td></tr>
<tr><td colspan="2">Problems at Almaraz - nuclear power plant is located ≈100 km upstream the boarder Portugal/Spain, on the bank of Tagus river. If an accident occurs, water may be contaminated either by propagation of the nuclear radiation by air or by the river.</td></tr>
<tr><td>Influenced by:
n/a</td><td>with the following barriers:
n/a</td></tr>
<tr><td colspan="2">Probability class: Low (1/1000 - 1/100)
A study is undergoing to find out more about this subject.</td></tr>
<tr><td>Impact on:
28 - Diffuse pollution (Event)
29 – Point source pollution (Event)</td><td>with the following barriers:
- Stakeholders engagement (_____) --> 28</td></tr>
<tr><td colspan="2">Related with the following strategic risk(s):
Lack of adequate Water Quality supplied</td></tr>
</table>

27

Forest fires

Event

The land use around C.Bode is mostly comprised by forest areas, many of which usually are set on fire on the summer seasons. If the magnitude and location of the burnt areas are such that ashes get into the reservoir (either via atmosphere or following heavy rain episodes), the raw water quality may be affected by higher turbidity and HAPC (hydro carbonates).

Influenced by:	with the following barriers:
n/a	n/a

Probability class: **High (1/10 - 1/1)**

Until now, severity of the forest fires has been such that did not affect the treatment of water at Asseiceira.

Impact on:	with the following barriers:
31 - Reduced water quality / contamination at sources (Exposure)	- Stakeholders engagement (_____) --> 32

Related with the following strategic risk(s):
Lack of adequate Water Quality supplied

28

Diffuse pollution

Event

Diffuse pollution may occur in the watershed upstream the water sources or along the supply system. It may be due to agriculture practices (pesticides, nitrates, phosphates) or to cattle (organic matter, crypto, giardia).

Influenced by:	with the following barriers:
n/a	n/a

Probability class: **Certain (1/1)**

It is detected in raw water.

Impact on:	with the following barriers:
31 - Reduced water quality / contamination at sources (Exposure) 32 - Reduced water quality / contamination in the Transport or Distribution system (Exposure)	- Stakeholders engagement (_____) --> 31 - AM best practices (_____) --> 32 - Mix sources (_____) --> 32

Related with the following strategic risk(s):
Lack of adequate Water Quality supplied

<table>
<tr><td rowspan="6">29</td><td colspan="2">Point source pollution
Event</td></tr>
<tr><td colspan="2">Point source pollution may occur in the watershed upstream water sources or along the supply system. It may be due to treated or untreated wastewater discharges, to spillage of dangerous substances or to the leaking from landfills or quarries. In the distribution system, it may also be due to contamination during maintenance actions.</td></tr>
<tr><td>Influenced by:
n/a</td><td>with the following barriers:
n/a</td></tr>
<tr><td colspan="2">Probability class: Certain (1/1)
Wastewater is the major contribution.</td></tr>
<tr><td>Impact on:
31 - Reduced water quality / contamination at sources (Exposure)
32 - Reduced water quality / contamination in the Transport or Distribution system (Exposure)</td><td>with the following barriers:
- Stakeholders engagement (_____) --> 31
- AM best practices (_____) --> 32</td></tr>
<tr><td colspan="2">Related with the following strategic risk(s):
Lack of adequate Water Quality supplied</td></tr>
</table>

<table>
<tr><td rowspan="6">30</td><td colspan="2">Vandalism
Event</td></tr>
<tr><td colspan="2">An act of vandalism within water supply system that may put in danger asset integrity or the safety of the delivered water quality.</td></tr>
<tr><td>Influenced by:
n/a</td><td>with the following barriers:
n/a</td></tr>
<tr><td colspan="2">Probability class: Certain (1/1)
It has been occuring in the last years</td></tr>
<tr><td>Impact on:
31 - Reduced water quality / contamination at sources (Exposure)
32 - Reduced water quality / contamination in the Transport or Distribution system (Exposure)</td><td>with the following barriers:
- Increased security (_____) --> 31, 32, 40</td></tr>
<tr><td colspan="2">Related with the following strategic risk(s):
Lack of adequate Water Quality supplied</td></tr>
</table>

<table>
<tr><td rowspan="6">31</td><td>Reduced water quality / contamination at sources
Exposure</td></tr>
<tr><td>Water quality at surface or underground sources may decrease due to natural or anthropogenic causes. Contaminants may be biological, chemical, toxic or radioactive.</td></tr>
<tr><td>Influenced by:
25 - High temperatures / dry weather (Event)
26 - Radioactivity (Problems at Almaraz) (Event)
27 - Forest fires (Event)
28 - Diffuse pollution (Event)
29 – Point source pollution (Event)
30 - Vandalism (Event)

with the following barriers:
- Stakeholders engagement (_____) --> 31
- Increased security (_____) --> 31, 32, 40</td></tr>
<tr><td>Probability class: Certain (1/1)
Due to the point source and diffuse pollution that occurs at Valada-Tejo, Ota and Alenquer.
A recent study has shown that Panasqueira mines' landfill pose no threat to raw water quality at C.Bode.</td></tr>
<tr><td>Impact on:
32 - Reduced water quality / contamination in the Transport or Distribution system (Exposure)
44 - Critical infrastructures' unavailability for an extended period (Harm)

with the following barriers:
- WTPs' efficiency (_____) --> 32
- Sources' diversification (_____) --> 44,32
- Increase system's flexibility (_____) --> 44</td></tr>
<tr><td>Related with the following strategic risk(s):
Lack of adequate Water Quality supplied
Disruption in the water supply</td></tr>
</table>

<table>
<tr><td rowspan="6">32</td><td colspan="2">Reduced water quality / contamination in the Transport or Distribution system
Exposure</td></tr>
<tr><td colspan="2">Water quality in the transport or distribution system may decrease due to contamination from the source or directly in the supply system. This latter is specially relevant in Alviela and Tagus aqueducts (free surface flow) and mainly at Alviela (very bad condition; water pressure drains). It may also occur due to an overcapacity of the mains that lead to a decrease in the flow velocity.</td></tr>
<tr><td>Influenced by:
21 - Overcapacity of the assets (Exposure)
28 - Diffuse pollution (Event)
29 – Point source pollution (Event)
30 - Vandalism (Event)
34 - Inadequate AM practices / design / operation / maintenance (Event)
31 - Reduced water quality / contaminatimation at sources</td><td>with the following barriers:
- WTPs' efficiency (_____) --> 32
- Sources' diversification (_____) --> 44,32
- AM best practices (_____) --> 32</td></tr>
<tr><td colspan="2">Probability class: Moderate to High (1/100 -1/1)
Vale da Pedra WTP is not so robust as Asseiciera WTP, but the mix of waters prove to be effective.
Analysis to samples in the Transport or Distribution system indicate that direct contamination is not relevant, although Alviela aqueduct's vulnerability is very high.</td></tr>
<tr><td>Impact on:
33 - Presence of contaminants in the delivery points (biological, chemical, toxic, radioactive) (Harm)
44 - Critical infrastructures' unavailability for an extended period (Harm)</td><td>with the following barriers:
- PCQA (_____) --> 33, 44
- Online monitoring (_____) --> 33, 44
- Optimal location of disinfection points (_____) --> 33, 44
- Increase system's flexibility (_____) --> 44</td></tr>
<tr><td colspan="2">Related with the following strategic risk(s):
Lack of adequate Water Quality supplied
Disruption in the water supply</td></tr>
</table>

<table>
<tr><td rowspan="6">33</td><td colspan="2">Presence of contaminants in the delivery points (biological, chemical, toxic, radioactive)
Harm</td></tr>
<tr><td colspan="2">Presence of contaminants in the delivery points in such a way that may affect consumers health.</td></tr>
<tr><td>Influenced by:
32 - Reduced water quality / contamination in the Transport or Distribution system (Exposure)</td><td>with the following barriers:
- PCQA (_____) --> 33, 44
- Online monitoring (_____) --> 33, 44
- Optimal location of disinfection points (_____) --> 33, 44</td></tr>
<tr><td colspan="2">Probability class: Low (1/1000 - 1/100)</td></tr>
<tr><td>Impact on:
(strategic objective)</td><td>with the following barriers:
- Business continuity (contigency plans)
- PCQA</td></tr>
<tr><td colspan="2">Related with the following strategic risk(s):
Lack of adequate Water Quality supplied</td></tr>
</table>

<table>
<tr><td rowspan="6">34</td><td colspan="2">Inadequate AM practices / design / operation / maintenance
Event</td></tr>
<tr><td colspan="2">Inadequate AM practices / design / operation / maintenance due to poorly qualified workers, insufficient supervising or other control measures, financial or time constraints, etc.</td></tr>
<tr><td>Influenced by:
n/a</td><td>with the following barriers:
n/a</td></tr>
<tr><td colspan="2">Probability class: High (1/10 - 1/1)
More than 200 employees are aged 55+ and there is no HR strategic plan. Government rules do not allow the recruitment of new people.</td></tr>
<tr><td>Impact on:
32 - Reduced water quality / contamination in the Transport or Distribution system (Exposure)
40 - Critical assets' failure (Exposure)</td><td>with the following barriers:
- AM best practices (_____) --> 40, 31</td></tr>
<tr><td colspan="2">Related with the following strategic risk(s):
Disruption in the water supply</td></tr>
</table>

<table>
<tr><td rowspan="6">35</td><td colspan="2">Assets natural ageing
Event</td></tr>
<tr><td colspan="2">EPAL's water supply system is comprised by recent sub-systems (ex.: C.Bode, Circunvalação, V.F.Xira-Telheiras, significant part of Distribution network) but also by old systems (Alviela, Tejo, part of Distribution network).
The likelihood of failure of the latter is getting higher, although these are not the most critical infrastructures (with exception to V.Pedra WTP, which will soon be refurbished).</td></tr>
<tr><td>Influenced by:
n/a</td><td>with the following barriers:
n/a</td></tr>
<tr><td colspan="2">Probability class: Moderate (1/100 - 1/10)
MSc. thesis “Forecasting the failure probability for water mains" (Padmraj Patil) evidences that failures in trunk mains will occur within the next 100 years.</td></tr>
<tr><td>Impact on:
40 - Critical assets' failure (Exposure)</td><td>with the following barriers:
- AM best practices (_____) --> 40</td></tr>
<tr><td colspan="2">Related with the following strategic risk(s):
Disruption in the water supply</td></tr>
</table>

<table>
<tr><td rowspan="6">36</td><td colspan="2">Very bad weather conditions
Event</td></tr>
<tr><td colspan="2">Bad or extreme events such as tornados and floods may destroy assets, contaminate water and/or affect power production and distribution.</td></tr>
<tr><td>Influenced by:
n/a</td><td>with the following barriers:
n/a</td></tr>
<tr><td colspan="2">Probability class: Moderate (1/100 - 1/10)
"Mini-tornados have been occurring in recent years".</td></tr>
<tr><td>Impact on:
40 - Critical assets' failure (Exposure)
41 - Power outage (Exposure)</td><td>with the following barriers:
- Structural protection of the assets (_____) --> 40</td></tr>
<tr><td colspan="2">Related with the following strategic risk(s):
Disruption in the water supply</td></tr>
</table>

37

Failure in the suppliers' / contractors' / service

Event

Suppliers/contractors fail to meet agreed service due to economic, social or other reasons.

Influenced by:	with the following barriers:
n/a	

Probability class: **Certain (1/1)**

EPAL has already experienced contractor's bankruptcy, due to the actual economic crisis.
For some of the products, there is no stock.
In some cases there is a high dependence on one supplier.
The process is controlled and stable, but there is a need to improve the process of evaluating the suppliers.

Impact on:	with the following barriers:
41 - Power outage (Exposure) 42 - Dependence on supply of chemicals, materials, equipment, services (Exposure)	- Ready available alternatives (_____) --> 41, 42

Related with the following strategic risk(s):
Disruption in the water supply

38

Strikes

Event

Occurence of strikes in EPAL.

Influenced by:	with the following barriers:
n/a	n/a

Probability class: **Certain (1/1)**

It has occured in the last years and the economic and financial crisis tend to increase the frequency of strikes.

Impact on:	with the following barriers:
43 - Insufficient human resources to operate the system (Exposure)	- Minimum services guaranteed (_____) --> 43

Related with the following strategic risk(s):
Disruption in the water supply

<table>
<tr><td rowspan="6">39</td><td colspan="2">Pandemic
Event</td></tr>
<tr><td colspan="2"></td></tr>
<tr><td>Influenced by:</td><td>with the following barriers:</td></tr>
<tr><td colspan="2">Probability class: Very Low (1/10000 - 1/1000)</td></tr>
<tr><td>Impact on:</td><td>with the following barriers:</td></tr>
<tr><td colspan="2">Related with the following strategic risk(s):</td></tr>
</table>

<table>
<tr><td rowspan="6">40</td><td colspan="2">Critical assets' failure
Exposure</td></tr>
<tr><td colspan="2">Failure of the assets due to mechanical, electrical or structural problems.</td></tr>
<tr><td>Influenced by:
30 - Vandalism (Event)
34 - Inadequate AM practices / design / operation / maintenance (Event)
35 - Assets natural ageing (Event)
36 - Tornados, floods, earthquakes (Event)</td><td>with the following barriers:
- Structural protection of the assets (_____) --> 40
- AM best practices (_____) --> 40
- Increased security (_____) --> 31, 32, 40</td></tr>
<tr><td colspan="2">Probability class: Moderate (1/100 - 1/10)</td></tr>
<tr><td>Impact on:
44 - Critical infrastructures' unavailability for an extended period (Harm)</td><td>with the following barriers:
- Increase system's flexibility (_____) --> 44</td></tr>
<tr><td colspan="2">Related with the following strategic risk(s):
Disruption in the water supply</td></tr>
</table>

41 Power outage

Exposure

Power outage may be caused by internal problems in the power supply system or be due to natural catastrophes.

Influenced by:	with the following barriers:
36 - Tornados, floods, earthquakes (Event) 37 - Failure in the suppliers' / contractors' / service (Event)	- Ready available alternatives (_____) --> 41, 42

Probability class: **Moderate (1/100 - 1/10)**

"A major natural catastrophe is due to happen in 50 years".

Impact on:	with the following barriers:
44 - Critical infrastructures' unavailability for an extended period (Harm)	- Increase system's flexibility (_____) --> 44

Related with the following strategic risk(s):
Disruption in the water supply

42 Dependence on supply of chemicals, materials, equipment, services

Exposure

The system functionality is highly dependent on the supply of chemicals, materials, equipments and, in some cases, outsourced work force.

Influenced by:	with the following barriers:
37 - Failure in the suppliers' / contractors' / service (Event)	- Ready available alternatives (_____) --> 41, 42

Probability class: **Certain (1/1)**

Impact on:	with the following barriers:
44 - Critical infrastructures' unavailability for an extended period (Harm)	- Increase system's flexibility (_____) --> 44

Related with the following strategic risk(s):
Disruption in the water supply

<table>
<tr><td rowspan="7">43</td><td>Insufficient human resources to operate the system
Exposure</td></tr>
<tr><td>Unavailability of human resources in such a way that water supply system can not be operated, due to to social problems (demonstrations, strikes, etc.) or to pandemic.</td></tr>
<tr><td>Influenced by:
38 - Strikes (Event)

with the following barriers:
- Minimum services guaranteed (_____) --> 43</td></tr>
<tr><td>Probability class: Moderate to High (1/100 -1/1)
Social tension is high, but awareness of EPAL's mission is also high.</td></tr>
<tr><td>Impact on:
44 - Critical infrastructures' unavailability for an extended period (Harm)

with the following barriers:
- Increase system's flexibility (_____) --> 44</td></tr>
<tr><td>Related with the following strategic risk(s):
Disruption in the water supply</td></tr>
</table>

<table>
<tr><td rowspan="7">44</td><td>Critical infrastructures' unavailability for an extended period
Harm</td></tr>
<tr><td>Critical assets unavailability for an extended period, due to mechanical, electrical or structural failure, to lack of chemicals to treat water, to lack of people to operate the system, to a power outage or to the presence of contaminated water in the system.</td></tr>
<tr><td>Influenced by:
31 - Reduced water quality / contamination at sources (Exposure)
32 - Reduced water quality / contamination in the Transport or Distribution system (Exposure)
40 - Critical assets' failure (Exposure)
41 - Power outage (Exposure)
42 - Dependence on supply

with the following barriers:
- WTPs' efficiency (___) --> 44
- PCQA (_____) --> 33, 44
- Online monitoring (_____) --> 33, 44
- Optimal location of disinfection points (_____) --> 33, 44
- Sources' diversification (___) --> 44
- Increase system's flexibility (___) --> 44</td></tr>
<tr><td>Probability class: Moderate (1/100 - 1/10)</td></tr>
<tr><td>Impact on:
(strategic objective)

with the following barriers:
- Business continuity (contigency plans)</td></tr>
<tr><td>Related with the following strategic risk(s):
Disruption in the water supply</td></tr>
</table>

<table>
<tr><td rowspan="6">45</td><td colspan="2">Water losses increase
Event</td></tr>
<tr><td colspan="2">Water losses (either in EPAL's system or in the distribution systems of the Municipal Clients) may increase due to ageing of the mains and to insufficient maintenance or renewal practices.</td></tr>
<tr><td>Influenced by:
n/a</td><td>with the following barriers:
n/a</td></tr>
<tr><td colspan="2">Probability class: Low (1/1000 - 1/100)</td></tr>
<tr><td>Impact on:
50 - Increase in the demand (Exposure)</td><td>with the following barriers:
-</td></tr>
<tr><td colspan="2">Related with the following strategic risk(s):
Lack of adequate Water Quantity supplied</td></tr>
</table>

<table>
<tr><td rowspan="6">46</td><td colspan="2">Consumption increase
Event</td></tr>
<tr><td colspan="2">Consumption may increase due to an increase in population or in economic activity.</td></tr>
<tr><td>Influenced by:
n/a</td><td>with the following barriers:
n/a</td></tr>
<tr><td colspan="2">Probability class: Very Low (1/10000 - 1/1000)</td></tr>
<tr><td>Impact on:
50 - Increase in the demand (Exposure)</td><td>with the following barriers:
- Marketing (_____) --> 50</td></tr>
<tr><td colspan="2">Related with the following strategic risk(s):
Lack of adequate Water Quantity supplied</td></tr>
</table>

<table>
<tr><td rowspan="6">47</td><td>Droughts / Capture in Spain
Event</td></tr>
<tr><td>Occurence of severe or extreme droughts, which may lead to retention of water in the Spanish basin of Tagus River.</td></tr>
<tr><td>Influenced by:
n/a
with the following barriers:</td></tr>
<tr><td>Probability class: Low (1/1000 - 1/100)
Adaptaclima project foresees that extreme droughts will occur within the next 20 years, but C. Bode reservoir is very resilient and it will not happen during this hydrological year.</td></tr>
<tr><td>Impact on:
51 - Reduced water availability at sources (Exposure)
with the following barriers:
-</td></tr>
<tr><td>Related with the following strategic risk(s):
Lack of adequate Water Quantity supplied</td></tr>
</table>

<table>
<tr><td rowspan="6">48</td><td>High turbination or major works at C.Bode
Event</td></tr>
<tr><td>C.Bode reservoir is shared with EDP that uses it for electricity production. If the turbination lowers the water level below EPAL's intakes, EPAL will not be able to abstract water from that source.</td></tr>
<tr><td>Influenced by:
n/a
with the following barriers:</td></tr>
<tr><td>Probability class: Low (1/1000 - 1/100)
It is safeguarded in EDP's concession contract with APA that they cannot turbinate below a level that compromises EPAL.</td></tr>
<tr><td>Impact on:
51 - Reduced water availability at sources (Exposure)
with the following barriers:
- Relation with EDP (_____) --> 51
- C.Bode reservoir management commission (_____) --> 51</td></tr>
<tr><td>Related with the following strategic risk(s):
Lack of adequate Water Quantity supplied</td></tr>
</table>

50

Increase in the demand

Exposure

Increase in the demand (by actual clients) result from an effective increase in consumption and/or an increase in water losses.

Influenced by:
45 - Water losses increase (Event)
46 - Consumption increase (Event)

with the following barriers:

Probability class: **Very Low (1/10000 - 1/1000)**

Impact on:
53 - Supply/Demand balance in deficit (Harm)

with the following barriers:
-

Related with the following strategic risk(s):
Lack of adequate Water Quantity supplied

51

Reduced water availability at sources

Exposure

Water availability at sources is reduced due to the occurence of droughts or, for C.Bode, problems at the dam/high turbination.

Influenced by:
47 - Droughts / Capture in Spain (Event)
48 - High turbination or major works at C.Bode (Event)

with the following barriers:
- Relation with EDP (_____) --> 51
- C.Bode reservoir management commission (_____) --> 51

Probability class: **Low (1/1000 - 1/100)**

Adaptaclima project foresees that extreme droughts will occur within the next 20 years, but C. Bode reservoir is very resilient and it will not happen during this hydrological year.It is safeguarded in EDP's concession contract with APA that they cannot turbinate below a level that compromises EPAL.

Impact on:
53 - Supply/Demand balance in deficit (Harm)

with the following barriers:
- Sources' diversification (_____) --> 53

Related with the following strategic risk(s):
Lack of adequate Water Quantity supplied

<table>
<tr><td rowspan="6">49</td><td colspan="2">Undercapacity of the assets
Exposure</td></tr>
<tr><td colspan="2">Assets are underdesigned for the actual demand.</td></tr>
<tr><td>Influenced by:
3 - Inadequate long-term planning (Event)</td><td>with the following barriers:</td></tr>
<tr><td colspan="2">Probability class: Very Low to Low (1/10000 - 1/100)</td></tr>
<tr><td>Impact on:
52 - Water doesn't flow from sources to the delivery points (Harm)</td><td>with the following barriers:
-</td></tr>
<tr><td colspan="2">Related with the following strategic risk(s):
Lack of adequate Water Quantity supplied</td></tr>
</table>

<table>
<tr><td rowspan="6">52</td><td colspan="2">Water doesn't flow from sources to the delivery points
Harm</td></tr>
<tr><td colspan="2">Assets are functioning but are not able to deliver the total demanded flow because of their undercapacity.</td></tr>
<tr><td>Influenced by:
49 - Undercapacity of the assets (Exposure)</td><td>with the following barriers:</td></tr>
<tr><td colspan="2">Probability class: Very Low (1/10000 - 1/1000)</td></tr>
<tr><td>Impact on:
(strategic objective)</td><td>with the following barriers:
- Business continuity (contigency plans)</td></tr>
<tr><td colspan="2">Related with the following strategic risk(s):
Lack of adequate Water Quantity supplied</td></tr>
</table>

<table>
<tr><td rowspan="6">53</td><td colspan="2">Supply/Demand balance in deficit
Harm</td></tr>
<tr><td colspan="2">The demand for water exceeds the availability at sources.</td></tr>
<tr><td>Influenced by:
50 - Increase in the demand (Exposure)
51 - Reduced water availability at sources (Exposure)</td><td>with the following barriers:</td></tr>
<tr><td colspan="2">Probability class: Low (1/1000 - 1/100)</td></tr>
<tr><td>Impact on:
(strategic objective)</td><td>with the following barriers:
- Business continuity (contigency plans)</td></tr>
<tr><td colspan="2">Related with the following strategic risk(s):
Lack of adequate Water Quantity supplied</td></tr>
</table>

<table>
<tr><td rowspan="6">54</td><td colspan="2">Pipe bursts in Lisbon network (abbrev.)
Event</td></tr>
<tr><td colspan="2">Pipe bursts occur every week in the distribution system. This can cause "brown water" to flow from taps (after the repair) and, in some cases, damages to private properties. Organoleptic issues may also arise from the operation conditions (low flow velocities).</td></tr>
<tr><td>Influenced by:
n/a</td><td>with the following barriers:</td></tr>
<tr><td colspan="2">Probability class: Certain (1/1)</td></tr>
<tr><td>Impact on:
58 - Non compliance of organoleptic parameters (Exposure)
59 - 3rd parties injured (Exposure)</td><td>with the following barriers:
- AM best practices (_____) --> 58, 59</td></tr>
<tr><td colspan="2">Related with the following strategic risk(s):
Reputation and trust compromised</td></tr>
</table>

55	**Fraud, non-compliance with Ethic Code** *Event*	
	Fraud or other actions that do not comply with EPAL's ethic code.	
	Influenced by: n/a	with the following barriers:
	Probability class: **Low (1/1000 - 1/100)** The mechanisms to avoid non-compliances with Ethic Code exist.	
	Impact on: 59 - 3rd parties injured (Exposure)	with the following barriers:
	Related with the following strategic risk(s): Reputation and trust compromised	

56	**Health and Safety of employees compromised** *Event*	
	Employees may be seriously injured (or killed) during their working activities.	
	Influenced by: n/a	with the following barriers: n/a
	Probability class: **Moderate (1/100 - 1/10)**	
	Impact on: 59 - 3rd parties injured (Exposure)	with the following barriers: -
	Related with the following strategic risk(s): Reputation and trust compromised	

<table>
<tr><td rowspan="6">57</td><td colspan="2">Inadequate relationship with Unions / Media / Stakeholders
Event</td></tr>
<tr><td colspan="2">An inadequate relationship with Unions/Media/Stakeholders may lead to an increse in the release of defaming news.</td></tr>
<tr><td>Influenced by:
n/a</td><td>with the following barriers:
n/a</td></tr>
<tr><td colspan="2">Probability class: Moderate (1/100 - 1/10)
It has happened in the past.</td></tr>
<tr><td>Impact on:
60 - Power to influence public opinion (Exposure)</td><td>with the following barriers:
-</td></tr>
<tr><td colspan="2">Related with the following strategic risk(s):
Reputation and trust compromised</td></tr>
</table>

<table>
<tr><td rowspan="6">58</td><td colspan="2">Non compliance of organoleptic parameters
Exposure</td></tr>
<tr><td colspan="2">Organoleptic parameters (colour, smell, taste) may be beyond the required level.</td></tr>
<tr><td>Influenced by:
54 - Pipe bursts in Lisbon network (abbrev.) (Event)</td><td>with the following barriers:
- AM best practices (_____) --> 58, 59</td></tr>
<tr><td colspan="2">Probability class: Low (1/1000 - 1/100)
Number of claims is low.</td></tr>
<tr><td>Impact on:
61 - Public opinion damage (Harm)</td><td>with the following barriers:
- Information to the customers (_____) --> 61</td></tr>
<tr><td colspan="2">Related with the following strategic risk(s):
Reputation and trust compromised</td></tr>
</table>

<table>
<tr><td rowspan="6">59</td><td colspan="2">3rd parties injured
Exposure</td></tr>
<tr><td colspan="2">3rd parties may be injured due to the occurence of pipe bursts, non-compliance with ethical code or health and safety failure.</td></tr>
<tr><td>Influenced by:
54 - Pipe bursts in Lisbon network (abbrev.) (Event)
55 - Fraud, non-compliance with Ethic Code (Event)
56 - Health and Safety of employees compromised (Event)</td><td>with the following barriers:
- AM best practices (_____) --> 58, 59</td></tr>
<tr><td colspan="2">Probability class: Moderate (1/100 - 1/10)
Mainly due to pipe bursts in Lisbon.</td></tr>
<tr><td>Impact on:
61 - Public opinion damage (Harm)</td><td>with the following barriers:
- Adequate compensation policy (_____) --> 61
- Re-enforcement of positive image (_____) --> 61</td></tr>
<tr><td colspan="2">Related with the following strategic risk(s):
Reputation and trust compromised</td></tr>
</table>

<table>
<tr><td rowspan="6">60</td><td colspan="2">Power to influence public opinion
Exposure</td></tr>
<tr><td colspan="2">Unions, media and stakeholders have the power to influence public opinion, through the release of defaming news.</td></tr>
<tr><td>Influenced by:
57 - Inadequate relationship with Unions / Media / Stakeholders (Event)</td><td>with the following barriers:</td></tr>
<tr><td colspan="2">Probability class: Certain (1/1)</td></tr>
<tr><td>Impact on:
61 - Public opinion damage (Harm)</td><td>with the following barriers:
- Re-enforcement of positive image (_____) --> 61</td></tr>
<tr><td colspan="2">Related with the following strategic risk(s):
Reputation and trust compromised</td></tr>
</table>

<table>
<tr><td rowspan="7">61</td><td colspan="2">Public opinion damage
Harm</td></tr>
<tr><td colspan="2">Damage in public opinion may arise from "direct causes" (non-compliance with organolectic parameters, 3rd parties injured, inadequate relationship with syndicates and media) or "indirect causes" (failure to achieve each of the other strategic objectives).</td></tr>
<tr><td>Influenced by:
60 - Power to influence public opinion (Exposure)
59 - 3rd parties injured (Exposure)
58 - Non compliance of organoleptic parameters (Exposure)</td><td>with the following barriers:
- Adequate compensation policy (_____) --> 61
- Information to the customers (_____) --> 61
- Re-enforcement of positive image (_____) --> 61</td></tr>
<tr><td colspan="2">Probability class: Moderate (1/100 - 1/10)
The range is due to the contribution of both "direct" and "indirect causes".</td></tr>
<tr><td>Impact on:
(strategic objective)</td><td>with the following barriers:
- Re-enforcement of positive image
- Contingency plans</td></tr>
<tr><td colspan="2">Related with the following strategic risk(s):
Reputation and trust compromised</td></tr>
</table>

<table>
<tr><td rowspan="7">100</td><td colspan="2">Inadequate governance
Risk factor</td></tr>
<tr><td colspan="2">Inadequate governance may be due to an excessive interference of the Government in EPAL's management. It has effects on the image (identification of EPAL with the image of the public sector in general), on the approval of investments, on the salaries and EPAL's capacity to capture talent, etc. (Profitability), etc.</td></tr>
<tr><td>Influenced by:</td><td>with the following barriers:</td></tr>
<tr><td colspan="2">Probability class:</td></tr>
<tr><td>Impact on:</td><td>with the following barriers:</td></tr>
<tr><td colspan="2">Related with the following strategic risk(s):</td></tr>
</table>

<table>
<tr><td rowspan="6">101</td><td colspan="2">Lack of communication
Risk factor</td></tr>
<tr><td colspan="2">Lack of communication between people (especially from different departments) may lead to several inefficiencies in the processes. It affects profitability (unoptimized working processes) and may affect the disruption in the supply or the health and safety of employees.</td></tr>
<tr><td>Influenced by:</td><td>with the following barriers:</td></tr>
<tr><td colspan="2">Probability class:</td></tr>
<tr><td>Impact on:</td><td>with the following barriers:</td></tr>
<tr><td colspan="2">Related with the following strategic risk(s):</td></tr>
</table>

<table>
<tr><td rowspan="6">102</td><td colspan="2">Poor HR practices
Risk factor</td></tr>
<tr><td colspan="2">Poor HR practices result from difficulties in capturing talent to the company; in ensuring that knowledge transfer is made when employees get retired or move to another company; and also in renewing "minds" in the company ("familiar dynasties"). This directly affects AM practices.

NOTE: >200 / 700 employees are aged 55+</td></tr>
<tr><td>Influenced by:</td><td>with the following barriers:</td></tr>
<tr><td colspan="2">Probability class:</td></tr>
<tr><td>Impact on:</td><td>with the following barriers:</td></tr>
<tr><td colspan="2">Related with the following strategic risk(s):</td></tr>
</table>

<table>
<tr><td rowspan="6">103</td><td colspan="2">Legal non-compliance
Risk factor</td></tr>
<tr><td colspan="2">Non-compliance with current legislation. It affects reputation and trust.</td></tr>
<tr><td>Influenced by:</td><td>with the following barriers:</td></tr>
<tr><td colspan="2">Probability class:</td></tr>
<tr><td>Impact on:</td><td>with the following barriers:</td></tr>
<tr><td colspan="2">Related with the following strategic risk(s):</td></tr>
</table>

<table>
<tr><td rowspan="6">104</td><td colspan="2">Inadequate data/information
Risk factor</td></tr>
<tr><td colspan="2">Inadequate data or information about the different subjects of the company - namely the assets - leads to an increase in the innefficiency of the processes and to bad decision-making (affects Profitability).</td></tr>
<tr><td>Influenced by:</td><td>with the following barriers:</td></tr>
<tr><td colspan="2">Probability class:</td></tr>
<tr><td>Impact on:</td><td>with the following barriers:</td></tr>
<tr><td colspan="2">Related with the following strategic risk(s):</td></tr>
</table>

Appendix G – Validation workshop main outcomes: revised events, exposure and harms' records and narratives

1. REVISED RECORDS

<table>
<tr><td rowspan="7">1</td><td colspan="2">Competition in water supply
Event</td></tr>
<tr><td colspan="2">Municipalities may start producing their own water (in case the price of water gets too high for them, for example)</td></tr>
<tr><td>Influenced by:
n/a</td><td>with the following barriers:
n/a</td></tr>
<tr><td colspan="2">Probability class: Moderate (1/100 - 1/10) Confidence: High
-</td></tr>
<tr><td>Impact on:
6 - Loss of monopoly (Exposure)</td><td>with the following barriers:
- Contractual safeguards (E=3, V=4, NC) --> 6
- Competitive advantadges (E=2, V=2, C) --> 6</td></tr>
<tr><td colspan="2">Related with the following strategic risk(s):
Business Sustainability compromised</td></tr>
</table>

<table>
<tr><td rowspan="7">2</td><td colspan="2">Non-revenue from municipal clients
Event</td></tr>
<tr><td colspan="2">Municipal clients do not pay their water bills either because they cannot afford them or because they do not want to (litigation).</td></tr>
<tr><td>Influenced by:
n/a</td><td>with the following barriers:
n/a</td></tr>
<tr><td colspan="2">Probability class: Moderate to High (1/100 -1/1) Confidence: Moderate
Taking into account the economic and financial situation of Portugal.</td></tr>
<tr><td>Impact on:
7 - Inability to cope with high fixed costs (Exposure)</td><td>with the following barriers:
- Quality of service (E=2, V=3, C) --> 7
- Monitor customer debt (E=5, V=5, NC) --> 7</td></tr>
<tr><td colspan="2">Related with the following strategic risk(s):
Business Sustainability compromised</td></tr>
</table>

<table>
<tr><td rowspan="7">3</td><td colspan="2">Inadequate long-term planning
Event</td></tr>
<tr><td colspan="2">Long-term planning does not anticipate assets' needs or demand evolution, leading to bad resource allocation (maintenance, rehabilitation) or inadequate assets' design (over or undercapacity of the assets).</td></tr>
<tr><td>Influenced by:
n/a</td><td>with the following barriers:
n/a</td></tr>
<tr><td colspan="2">Probability class: Moderate to High (1/100 -1/1) Confidence: Moderate
The existing Master Plan may not be perfect ("How far will the decrease in the consumption go?"), but it might be compensated by the increase in the knowledge about the assets that has been occurring. The planning is not rigid, and to a certain extent it can be adjusted in face of reality.</td></tr>
<tr><td>Impact on:
8 - Bad resource allocation (Exposure)
21 - Overcapacity of the assets (Exposure)
49 - Undercapacity of the assets (Exposure)</td><td>with the following barriers:
- Periodic review (E=1, V=1, NC) --> 8, 21, 49</td></tr>
<tr><td colspan="2">Related with the following strategic risk(s):
Business Sustainability compromised</td></tr>
</table>

<table>
<tr><td rowspan="6">4</td><td colspan="2">Inadequate relationship with banks
Event</td></tr>
<tr><td colspan="2">Due to a bad reputation or to a bad financial health of EPAL, banks do not trust EPAL's capacity to pay the loans.</td></tr>
<tr><td>Influenced by:
n/a</td><td>with the following barriers:
n/a</td></tr>
<tr><td colspan="2">Probability class: Very Low to Low (1/10000 - 1/100) Confidence: High
"EPAL has a very good relationship with EIB".</td></tr>
<tr><td>Impact on:
9 - Lack of financing (Exposure)</td><td>with the following barriers:
- Build trusty relations (E=1, V=1, NC) --> 9
- Diverse banks (E=1, V=1, NC) --> 9</td></tr>
<tr><td colspan="2">Related with the following strategic risk(s):
Business Sustainability compromised</td></tr>
</table>

5	**Changes in politics/economy** *Event*	
	There is a lack of stability in politics/economy that may adversly impact the financing capacity as well as the operational costs of EPAL. Uncertainty about future is high.	
	Influenced by: n/a	with the following barriers: n/a
	Probability class: **Certain (1/1)**	*Confidence: High*
	Impact on: 9 - Lack of financing (Exposure)	with the following barriers: - Anticipate changes (E=4, V=4, NC) --> 9 - Diverse banks (E=1, V=1, NC) --> 9
	Related with the following strategic risk(s): Business Sustainability compromised	

6	**Loss of monopoly** *Exposure*	
	Influenced by: 1 - Competition in water supply (Event)	with the following barriers: - Contractual safeguards (E=3, V=4, NC) --> 6 - Competitive advantadges (E=2, V=2, C) --> 6
	Probability class: **Moderate (1/100 - 1/10)**	*Confidence: High*
	Impact on: 10 - Loss of market share (Harm)	with the following barriers: -
	Related with the following strategic risk(s): Business Sustainability compromised	

7	**Inability to cope with high fixed costs** *Exposure*	
	Influenced by: 2 - Non-revenue from municipal clients (Event)	with the following barriers: - Quality of service (E=2, V=3, C) --> 7 - Monitor customer debt (E=5, V=5, NC) --> 7
	Probability class: **Moderate to High (1/100 -1/1)**	*Confidence: Low*
	Impact on: 11 - Difficulties in raising self-capital (Harm)	with the following barriers: -
	Related with the following strategic risk(s): Business Sustainability compromised	

8	**Bad resource allocation** *Exposure*	
	Continuosly bad resource allocation, so that sustainability might be compromised.	
	Influenced by: 3 - Inadequate long-term planning (Event)	with the following barriers: - Periodic review (E=1, V=1, NC) --> 8, 21, 49
	Probability class: **Moderate (1/100 - 1/10)**	*Confidence: Moderate*
	Impact on: 12 - Excessive rehabilitation / maintenance needs (Harm)	with the following barriers: -
	Related with the following strategic risk(s): Business Sustainability compromised	

<table>
<tr><td rowspan="6">9</td><td colspan="2">Lack of financing
Exposure</td></tr>
<tr><td colspan="2">There is no financing to EPAL, due either to a bad relationship with banks or to changes in Politics/Economy.</td></tr>
<tr><td>Influenced by:
4 - Inadequate relationship with banks (Event)
5 - Changes in politics/economy (Event)</td><td>with the following barriers:
- Build trusty relations (E=1, V=1, NC) --> 9
- Diverse banks (E=1, V=1, NC) --> 9
- Anticipate changes (E=4, V=4, NC) --> 9</td></tr>
<tr><td>Probability class: Moderate (1/100 - 1/10)</td><td>Confidence: High</td></tr>
<tr><td>Impact on:
13 - Inability to meet investment needs (AM best practices) (Harm)</td><td>with the following barriers:
- Use cash flow (self-financing) (E=2, V=1, NC) --> 13
- Retained earnings (E=2, V=1, NC) --> 13</td></tr>
<tr><td colspan="2">Related with the following strategic risk(s):
Business Sustainability compromised</td></tr>
</table>

<table>
<tr><td rowspan="6">10</td><td colspan="2">Loss of market share
Harm</td></tr>
<tr><td colspan="2"></td></tr>
<tr><td>Influenced by:
6 - Loss of monopoly (Exposure)</td><td>with the following barriers:
-</td></tr>
<tr><td>Probability class: Moderate (1/100 - 1/10)</td><td>Confidence: High</td></tr>
<tr><td>Impact on:
(strategic objective)</td><td>with the following barriers:
-</td></tr>
<tr><td colspan="2">Related with the following strategic risk(s):
Business Sustainability compromised</td></tr>
</table>

11	**Difficulties in raising self-capital** *Harm*
	Influenced by: 7 - Inability to cope with high fixed costs (Exposure) with the following barriers: -
	Probability class: **Moderate to High (1/100 -1/1)** *Confidence: Moderate*
	Impact on: (strategic objective) with the following barriers: -
	Related with the following strategic risk(s): Business Sustainability compromised

12	**Excessive rehabilitation / maintenance needs** *Harm*
	Assets' condition and performance are such that the ammount of CAPEX and OPEX needed for the system to operate are so high that might compromise business sustainability.
	Influenced by: 8 - Bad resource allocation (Exposure) with the following barriers: -
	Probability class: **Moderate (1/100 - 1/10)** *Confidence: High*
	Impact on: (strategic objective) with the following barriers: -
	Related with the following strategic risk(s): Business Sustainability compromised

13	**Inability to meet investment needs (AM best practices)** *Harm*	
	The capacity to invest in new assets or in the renewal of the existing ones is not enough to cope with all the needs.	
	Influenced by: 9 - Lack of financing (Exposure)	with the following barriers: - Use cash flow (self-financing) (E=2, V=1, NC) --> 13 - Retained earnings (E=2, V=1, NC) --> 13
	Probability class: **Low (1/1000 - 1/100)**	*Confidence: High*
	Impact on: (strategic objective)	with the following barriers: -
	Related with the following strategic risk(s): Business Sustainability compromised	

14	**Increase in the price of energy** *Event*	
	Energy is the highest operational cost of the company, and its price has been increasing over the last years.	
	Influenced by: n/a	with the following barriers: n/a
	Probability class: **Certain (1/1)**	*Confidence: High*
	Impact on: 18 - High dependence on energy supply (Exposure)	with the following barriers: -
	Related with the following strategic risk(s): Business Profitability compromised	

<table>
<tr><td rowspan="6">15</td><td colspan="2">Economic Regulation - Lack of rule making
Event</td></tr>
<tr><td colspan="2">The regulatory model for EPAL is explained by rules and codes that are not sufficient to clarify what is expected from EPAL. Consequently, it is not clear the way how profitability should be evaluated as well as the way tariffs are approved by the regulator.</td></tr>
<tr><td>Influenced by:
n/a</td><td>with the following barriers:
n/a</td></tr>
<tr><td>Probability class: Certain (1/1)</td><td>Confidence: High</td></tr>
<tr><td>Impact on:
19 - Insufficient guidance in economic regulation (Exposure)</td><td>with the following barriers:
- Competitive advantages (E=2, V=2, NC) --> 19</td></tr>
<tr><td colspan="2">Related with the following strategic risk(s):
Business Profitability compromised</td></tr>
</table>

<table>
<tr><td rowspan="6">16</td><td colspan="2">Limitations in setting tariffs
Event</td></tr>
<tr><td colspan="2">Tariffs cannot be increased regardless the surplus that may be needed to cope with the fixed costs, due to regulation constraints. It depends upon a political decision.</td></tr>
<tr><td>Influenced by:
n/a</td><td>with the following barriers:
n/a</td></tr>
<tr><td>Probability class: Certain (1/1)</td><td>Confidence: High</td></tr>
<tr><td>Impact on:
20 - Decrease in sales (Exposure)</td><td>with the following barriers:
- Discuss with regulator (E=2/3, V=3, C) --> 20</td></tr>
<tr><td colspan="2">Related with the following strategic risk(s):
Business Profitability compromised</td></tr>
</table>

<table>
<tr><td rowspan="6">17</td><td colspan="2">Consumption decrease
Event</td></tr>
<tr><td colspan="2">Decrease in consumption of the actual customers, due to either change of practices, economics constraints or to a reduction in their water losses (for municipal or multimunicipal clients).</td></tr>
<tr><td>Influenced by:
n/a</td><td>with the following barriers:
n/a</td></tr>
<tr><td>Probability class: Certain (1/1)</td><td>Confidence: High</td></tr>
<tr><td>Impact on:
21 - Overcapacity of the assets (Exposure)
20 - Decrease in sales (Exposure)</td><td>with the following barriers:
- New clients (E=5, V=5, NC) --> 21, 20
- Increase market share (E=5, V=5, NC) --> 21, 20
- Contractual safeguards (E=5, V=5, NC) --> 20</td></tr>
<tr><td colspan="2">Related with the following strategic risk(s):
Business Profitability compromised</td></tr>
</table>

<table>
<tr><td rowspan="6">18</td><td colspan="2">High dependence on energy supply
Exposure</td></tr>
<tr><td colspan="2">The water supply system of EPAL is designed in such a way that energy is needed not only to abstract water from all of the current sources (superficial and urderground) but also to deliver it to the customers.</td></tr>
<tr><td>Influenced by:
14 - Increase in the price of energy (Event)</td><td>with the following barriers:
-</td></tr>
<tr><td>Probability class: Certain (1/1)</td><td>Confidence: High</td></tr>
<tr><td>Impact on:
22 - OPEX increase (Harm)</td><td>with the following barriers:
- Increase efficiency (E=4, V=4, NC) --> 22</td></tr>
<tr><td colspan="2">Related with the following strategic risk(s):
Business Profitability compromised</td></tr>
</table>

19

Insufficient guidance in economic regulation

Exposure

The regulatory model for EPAL is explained by rules and codes that are not sufficient to clarify what is expected from EPAL. Consequently, it is not clear the way how profitability should be evaluated as well as the way tariffs are approved by the regulator.

Influenced by:	with the following barriers:
15 - Economic Regulation - Lack of rule making (Event)	- Competitive advantages (E=2, V=2, NC) --> 19

Probability class: **High (1/10 - 1/1)** *Confidence: Moderate*

Impact on:	with the following barriers:
23 - Negative impact from economic regulation (Harm)	- Discuss with Regulator (E=2/3, V=3, C) --> 23

Related with the following strategic risk(s):
Business Profitability compromised

20

Decrease in sales

Exposure

Decrease in sales for the actual clients

Influenced by:	with the following barriers:
16 - Limitations in setting tariffs (Event) 17 - Consumption decrease (Event)	- Discuss with regulator (E=2/3, V=3, C) --> 20 - New clients (E=5, V=5, NC) --> 21, 20 - Increase market share (E=5, V=5, NC) --> 21, 20 - Contractual safeguards (E=5, V=5, NC) --> 20

Probability class: **High to Certain (1/10 - 1/1)** *Confidence: High*

Impact on:	with the following barriers:
24 - Difficulties in obtaining return on investments (Harm)	-

Related with the following strategic risk(s):
Business Profitability compromised

<table>
<tr><td rowspan="6">21</td><td colspan="2">Overcapacity of the assets
Exposure</td></tr>
<tr><td colspan="2">Assets had been designed taking into account na estimated level in demand that has proven to be excessive in the present (due to an inadequated planning or to a decrease in the consumption).</td></tr>
<tr><td>Influenced by:
3 - Inadequate long-term planning (Event)
17 - Consumption decrease (Event)</td><td>with the following barriers:
- New clients (E=5, V=5, NC) --> 21, 22
- Increase market share (E=5, V=5, NC) --> 21, 22
- Periodic review (E=1, V=1, NC) --> 9, 21, 52</td></tr>
<tr><td colspan="2">Probability class: Moderate to High (1/100 -1/1) Confidence: High</td></tr>
<tr><td>Impact on:
24 - Difficulties in obtaining return on investments (Harm)
32 - Reduced water quality / contamination in the Transport or Distribution system (Exposure)</td><td>with the following barriers:
- AM best practices (E=3, V=4, C) --> 24, 32</td></tr>
<tr><td colspan="2">Related with the following strategic risk(s):
Business Profitability compromised</td></tr>
</table>

<table>
<tr><td rowspan="6">22</td><td colspan="2">OPEX increase
Harm</td></tr>
<tr><td colspan="2">Operational costs may increase due to the increase on the different parcels that contribute to it, namely external supplies and services (FSE), including energy.</td></tr>
<tr><td>Influenced by:
18 - High dependence on energy supply (Exposure)</td><td>with the following barriers:
- Increase efficiency (E=4, V=4, NC) --> 22</td></tr>
<tr><td colspan="2">Probability class: High (1/10 - 1/1) Confidence: High</td></tr>
<tr><td>Impact on:
(strategic objective)</td><td>with the following barriers:
- Increase efficiency (E=4, V=4, NC)</td></tr>
<tr><td colspan="2">Related with the following strategic risk(s):
Business Profitability compromised</td></tr>
</table>

<table>
<tr><td rowspan="6">23</td><td colspan="2">Negative impact from economic regulation
Harm</td></tr>
<tr><td colspan="2">The regulatory model for EPAL is explained by rules and codes that are not sufficient to clarify what is expected from EPAL. Consequently, it is not clear the way how profitability should be evaluated as well as the way tariffs are approved by the regulator.</td></tr>
<tr><td>Influenced by:
19 - Insufficient guidance in economic regulation (Exposure)</td><td>with the following barriers:
- Discuss with Regulator (E=2/3, V=3, C) --> 23</td></tr>
<tr><td colspan="2">Probability class: Moderate to High (1/100 -1/1) Confidence: Moderate</td></tr>
<tr><td>Impact on:
(strategic objective)</td><td>with the following barriers:
-</td></tr>
<tr><td colspan="2">Related with the following strategic risk(s):
Business Profitability compromised</td></tr>
</table>

<table>
<tr><td rowspan="6">24</td><td colspan="2">Difficulties in obtaining return on investments
Harm</td></tr>
<tr><td colspan="2">Difficulties result from a decrease in sales and from an overcapacity of the assets, that were designed to supply higher levels of demand. It should be noted, though, that ROI is not always easy to be measured.</td></tr>
<tr><td>Influenced by:
21 - Overcapacity of the assets (Exposure)
20 - Decrease in sales (Exposure)</td><td>with the following barriers:
- AM best practices (E=3, V=4, C) --> 24, 32</td></tr>
<tr><td colspan="2">Probability class: Moderate (1/100 - 1/10) Confidence: Moderate</td></tr>
<tr><td>Impact on:
(strategic objective)</td><td>with the following barriers:</td></tr>
<tr><td colspan="2">Related with the following strategic risk(s):
Business Profitability compromised</td></tr>
</table>

<table>
<tr><td rowspan="6">25</td><td colspan="2">High temperatures / dry weather
Event</td></tr>
<tr><td colspan="2">The increase in the number of days per year with high temperatures (T>30 ºC) in dry weather may lead to a degradation of water quality in the superficial water sources (considering that pollution loads are as usual for that season).</td></tr>
<tr><td>Influenced by:
n/a</td><td>with the following barriers:
n/a</td></tr>
<tr><td colspan="2">Probability class: Certain (1/1) Confidence: High
It happened last summer in Valada-Tejo.</td></tr>
<tr><td>Impact on:
31 - Reduced water quality / contamination at sources (Exposure)</td><td>with the following barriers:
- Stakeholders engagement (E=5, V=n/a, NC) --> 31</td></tr>
<tr><td colspan="2">Related with the following strategic risk(s):
Lack of adequate Water Quality supplied</td></tr>
</table>

<table>
<tr><td rowspan="6">26</td><td colspan="2">Radioactivity (Problems at Almaraz)
Event</td></tr>
<tr><td colspan="2">Problems at Almaraz - nuclear power plant is located ≈100 km upstream the boarder Portugal/Spain, on the bank of Tagus river. If an accident occurs, water may be contaminated either by propagation of the nuclear radiation by air or by the river.</td></tr>
<tr><td>Influenced by:
n/a</td><td>with the following barriers:
n/a</td></tr>
<tr><td colspan="2">Probability class: Low (1/1000 - 1/100) Confidence: Moderate
A study is undergoing to find out more about this subject.</td></tr>
<tr><td>Impact on:
31 - Reduced water quality / contamination at sources (Exposure)</td><td>with the following barriers:
- Stakeholders engagement (E=5, V=n/a, NC) --> 31</td></tr>
<tr><td colspan="2">Related with the following strategic risk(s):
Lack of adequate Water Quality supplied</td></tr>
</table>

27	**Forest fires** *Event*	
	The land use around C.Bode is mostly comprised by forest areas, many of which usually are set on fire on the summer seasons. If the magnitude and location of the burnt areas are such that ashes get into the reservoir (either via atmosphere or following heavy rain episodes), the raw water quality may be affected by higher turbidity and HAPC (hydrocarbonates).	
	Influenced by: n/a	with the following barriers: n/a
	Probability class: **High (1/10 - 1/1)** *Confidence: Moderate* Until now, severity of the forest fires has been such that did not affect the treatment of water at Asseiceira.	
	Impact on: 31 - Reduced water quality / contamination at sources (Exposure)	with the following barriers: - Stakeholders engagement (E=5, V=n/a, NC) --> 31
	Related with the following strategic risk(s): Lack of adequate Water Quality supplied	

28	**Diffuse pollution** *Event*	
	Difuse pollution may occur in the watershed upstream the water sources or along the supply system. It may be due to agriculture practices (pesticides, nitrates, phosphates) or to cattle (organic matter, crypto, giardia).	
	Influenced by: n/a	with the following barriers: n/a
	Probability class: **Certain (1/1)** *Confidence: High* It is detected in raw water.	
	Impact on: 31 - Reduced water quality / contamination at sources (Exposure) 32 - Reduced water quality / contamination in the Transport or Distribution system (Exposure)	with the following barriers: - Stakeholders engagement (E=5, V=n/a, NC) --> 31 - Protected perimeters (E=3, V=n/a, NC) --> 31 - AM best practices (E=1, V=5, C) --> 32 - On line monitoring (E=1, V=1, C) --> 32 - PCQA (E=3, V=n/a, NC) --> 32
	Related with the following strategic risk(s): Lack of adequate Water Quality supplied	

29

Point source pollution

Event

Point source pollution may occur in the watershed upstream water sources or along the supply system. It may be due to treated or untreated wastewater discharges, to spillage of dangerous substances or to the leaking from landfills or quarries. In the distribution system, it may also be due to contamination during maintenance actions.

Influenced by:	with the following barriers:
n/a	n/a

Probability class: **Certain (1/1)** *Confidence: High*

Wastewater is the major contribution.

Impact on:	with the following barriers:
31 - Reduced water quality / contamination at sources (Exposure) 32 - Reduced water quality / contamination in the Transport or Distribution system (Exposure)	- Stakeholders engagement (E=5, V=n/a, NC) --> 31 - Protected perimeters (E=3, V=n/a, NC) --> 31 - AM best practices (E=1, V=5, C) --> 32 - On line monitoring (E=1, V=1, C) --> 32 - PCQA (E=3, V=n/a, NC) --> 32

Related with the following strategic risk(s):
Lack of adequate Water Quality supplied

30

Vandalism

Event

An act of vandalism within water supply system that may put in danger asset integrity or the safety of the delivered water quality.

Influenced by:	with the following barriers:
n/a	n/a

Probability class: **Certain (1/1)** *Confidence: High*

It has been occuring in the last years

Impact on:	with the following barriers:
31 - Reduced water quality / contamination at sources (Exposure) 32 - Reduced water quality / contamination in the Transport or Distribution system (Exposure) 40 - Critical assets' failure (Exposure)	- Increased security (E=3, V=5, NC) --> 31, 32, 40 - On line monitoring (E=1, V=1, C) --> 32 - PCQA (E=3, V=n/a, NC) --> 32

Related with the following strategic risk(s):
Lack of adequate Water Quality supplied

<table>
<tr><td rowspan="6">31</td><td>Reduced water quality / contamination at sources
Exposure</td></tr>
<tr><td>Water quality at surface or underground sources may decrease due to natural or anthropogenic causes. Contaminants may be biological, chemical, toxic or radioactive.</td></tr>
<tr><td>Influenced by:
25 - High temperatures / dry weather (Event)
26 - Radioactivity (Problems at Almaraz) (Event)
27 - Forest fires (Event)
28 - Diffuse pollution (Event)
29 – Point source pollution (Event)
30 - Vandalism (Event)

with the following barriers:
- Stakeholders engagement (E=5, V=n/a, NC) --> 31
- Protected perimeters (E=3, V=n/a, NC) --> 31
- Increased security (E=3, V=5, NC) --> 31, 32, 40</td></tr>
<tr><td>Probability class: Certain (1/1) Confidence: High
Due to the point source and diffuse pollution that occurs at Valada-Tejo, Ota and Alenquer.
A recent study has shown that Panasqueira mines' landfill pose no threat to raw water quality at C.Bode.</td></tr>
<tr><td>Impact on:
32 - Reduced water quality / contamination in the Transport or Distribution system (Exposure)
44 - Critical infrastructures' unavailability for an extended period (Harm)

with the following barriers:
- WTPs' efficiency (E=1, V=1, C) --> 44,32
- AM best practices (E=1, V=5, C) --> 32
- PCQA (E=3, V=n/a, NC) --> 32
- On line monitoring (E=1, V=1, C) --> 32
- Sources' diversification (E=1, V=1, NC) --> 44,32</td></tr>
<tr><td>Related with the following strategic risk(s):
Lack of adequate Water Quality supplied
Disruption in the water supply</td></tr>
</table>

<table>
<tr><td rowspan="6">32</td><td>Reduced water quality / contamination in the Transport or Distribution system
Exposure</td></tr>
<tr><td>Water quality in the transport or distribution system may decrease due to contamination from the source or directly in the supply system. This latter is specially relevant in Alviela and Tagus aqueducts (free surface flow) and mainly at Alviela (very bad condition; water pressure drains). It may also occur due to an overcapacity of the mains that lead to a decrease in the flow velocity.</td></tr>
<tr><td>Influenced by:
21 - Overcapacity of the assets (Exposure)
28 - Diffuse pollution (Event)
29 – Point source pollution (Event)
30 - Vandalism (Event)
34 - Inadequate AM practices / design / operation / maintenance (Event)
31 - Reduced water quality / contamination at sources

with the following barriers:
- WTPs' efficiency (E=1, V=1, C) --> 32,44
- Sources' diversification (E=1, V=1, NC) --> 44,32
- PCQA (E=3, V=n/a, NC) --> 32
- On line monitoring (E=1, V=1, C) --> 32
- AM best practices (E=1, V=5, C) --> 32</td></tr>
<tr><td>Probability class: Moderate to High (1/100 -1/1) Confidence: High
Vale da Pedra WTP is not so robust as Asseiciera WTP, but the mix of waters prove to be effective.
Analysis to samples in the Transport or Distribution system indicate that direct contamination is not relevant, although Alviela aqueduct's vulnerability is very high.</td></tr>
<tr><td>Impact on:
33 - Presence of contaminants in the delivery points (biological, chemical, toxic, radioactive) (Harm)
44 - Critical infrastructures' unavailability for an extended period (Harm)

with the following barriers:
- PCQA (E=3, V=n/a, NC) --> 33, 44
- Online monitoring (E=1, V=1, C) --> 33, 44
- Optimal location of disinfection points (E=1, V=1, NC) --> 33, 44
- AM best practices (E=1, V=5, C) --> 33</td></tr>
<tr><td>Related with the following strategic risk(s):
Lack of adequate Water Quality supplied
Disruption in the water supply</td></tr>
</table>

<table>
<tr><td rowspan="6">33</td><td colspan="2">Presence of contaminants in the delivery points (biological, chemical, toxic, radioactive)
Harm</td></tr>
<tr><td colspan="2">Presence of contaminants in the delivery points in such a way that may affect consumers health.</td></tr>
<tr><td>Influenced by:
32 - Reduced water quality / contamination in the Transport or Distribution system (Exposure)</td><td>with the following barriers:
- PCQA (E=3, V=n/a, NC) --> 33, 44
- Online monitoring (E=1, V=1, C) --> 33, 44
- AM best practices (E=1, V=5, C) --> 33
- Optimal location of disinfection points (E=1, V=1, NC) --> 33, 44</td></tr>
<tr><td colspan="2">Probability class: Low (1/1000 - 1/100) Confidence: High</td></tr>
<tr><td>Impact on:
(strategic objective)</td><td>with the following barriers:
- Business continuity - contigency plans (E=5, V=n/a, NC)</td></tr>
<tr><td colspan="2">Related with the following strategic risk(s):
Lack of adequate Water Quality supplied</td></tr>
</table>

<table>
<tr><td rowspan="6">34</td><td colspan="2">Inadequate AM practices / design / operation / maintenance
Event</td></tr>
<tr><td colspan="2">Inadequate AM practices / design / operation / maintenance due to poorly qualified workers, insufficient supervising or other control measures, financial or time constraints, etc.</td></tr>
<tr><td>Influenced by:
n/a</td><td>with the following barriers:
n/a</td></tr>
<tr><td colspan="2">Probability class: High (1/10 - 1/1) Confidence: High
More than 200 employees are aged 55+ and there is no HR strategic plan.
Government rules do not allow the recruitment of new people.</td></tr>
<tr><td>Impact on:
32 - Reduced water quality / contamination in the Transport or Distribution system (Exposure)
40 - Critical assets' failure (Exposure)</td><td>with the following barriers:
- AM best practices (E=1, V=5, C) --> 40, 32
- On line monitoring (E=1, V=1, C) --> 32
- PCQA (E=3, V=n/a, NC) --> 32</td></tr>
<tr><td colspan="2">Related with the following strategic risk(s):
Disruption in the water supply</td></tr>
</table>

35	**Assets natural ageing** *Event*
	EPAL's water supply system is comprised by recent sub-systems (ex.: C.Bode, Circunvalação, V.F.Xira-Telheiras, significant part of Distribution network) but also by old systems (Alviela, Tejo, part of Distribution network). The likelihood of failure of the latter is getting higher, although these are not the most critical infrastructures (with exception to V.Pedra WTP, which will soon be refurbished).
	Influenced by: n/a with the following barriers: n/a
	Probability class: **Moderate (1/100 - 1/10)** *Confidence: High* MSc. thesis "Forecasting the failure probability for water mains" (Padmraj Patil) evidences that failures in trunk mains will occur within the next 100 years.
	Impact on: 40 - Critical assets' failure (Exposure) with the following barriers: - AM best practices (E=1, V=5, C) --> 40
	Related with the following strategic risk(s): Disruption in the water supply

36	**Very bad weather conditions** *Event*
	Bad or extreme events such as tornados and floods may destroy assets, contaminate water and/or affect power production and distribution.
	Influenced by: n/a with the following barriers: n/a
	Probability class: **High (1/10 - 1/1)** *Confidence: Moderate* "Mini-tornados have been occurring in recent years".
	Impact on: 40 - Critical assets' failure (Exposure) 41 - Power / telecommunications outage (Exposure) with the following barriers: - Structural protection of the assets (E=3, V=3, NC) --> 40 - Stakeholders engagement (E=3, V=3, C) --> 41
	Related with the following strategic risk(s): Disruption in the water supply

<table>
<tr><td rowspan="6">37</td><td colspan="2">Failure in the suppliers' / contractors' / service
Event</td></tr>
<tr><td colspan="2">Suppliers/contractors fail to meet agreed service due to economic, social or other reasons.</td></tr>
<tr><td>Influenced by:
n/a</td><td>with the following barriers:</td></tr>
<tr><td colspan="2">Probability class: Certain (1/1) Confidence: High
EPAL has already experienced contractor's bankruptcy, due to the actual economic crisis.
For some of the products, there is no stock.
In some cases there is a high dependence on one supplier.
The process is controlled and stable, but there is a need to improve the process of evaluating the suppliers.</td></tr>
<tr><td>Impact on:
41 - Power / telecommunications outage (Exposure)
42 - Dependence on supply of chemicals, materials, equipment, services (Exposure)</td><td>with the following barriers:
- Ready available alternatives (E=5, V=5, C) --> 41, 42
- Stakeholders engagement (E=3, V=3, C) --> 41</td></tr>
<tr><td colspan="2">Related with the following strategic risk(s):
Disruption in the water supply</td></tr>
</table>

<table>
<tr><td rowspan="6">38</td><td colspan="2">Strikes
Event</td></tr>
<tr><td colspan="2">Occurence of strikes in EPAL.</td></tr>
<tr><td>Influenced by:
n/a</td><td>with the following barriers:
n/a</td></tr>
<tr><td colspan="2">Probability class: Certain (1/1) Confidence: High
It has occured in the last years and the economic and financial crisis tend to increase the frequency of strikes.</td></tr>
<tr><td>Impact on:
43 - Insufficient human resources to operate the system (Exposure)</td><td>with the following barriers:
- Minimum services guaranteed (E=1, V=3, C) --> 43
- Equipment automation (E=3, V=3, NC) --> 43</td></tr>
<tr><td colspan="2">Related with the following strategic risk(s):
Disruption in the water supply</td></tr>
</table>

<table>
<tr><td rowspan="6">39</td><td colspan="2">Pandemic
Event</td></tr>
<tr><td colspan="2"></td></tr>
<tr><td>Influenced by:</td><td>with the following barriers:
n/a</td></tr>
<tr><td colspan="2">Probability class: Very Low (1/10000 - 1/1000) Confidence: Moderate</td></tr>
<tr><td>Impact on:
43 - Insufficient human resources to operate the system (Exposure)</td><td>with the following barriers:
- Equipment automation (E=3, V=3, NC) --> 43</td></tr>
<tr><td colspan="2">Related with the following strategic risk(s):</td></tr>
</table>

<table>
<tr><td rowspan="6">40</td><td colspan="2">Critical assets' failure
Exposure</td></tr>
<tr><td colspan="2">Failure of the assets due to mechanical, electrical or structural problems.</td></tr>
<tr><td>Influenced by:
30 - Vandalism (Event)
34 - Inadequate AM practices / design / operation / maintenance (Event)
35 - Assets natural ageing (Event)
36 - Very bad weather conditions (Event)</td><td>with the following barriers:
- Structural protection of the assets (E=3, V=3, NC) --> 40
- AM best practices (E=1, V=5, C) --> 40
- Increased security (E=3, V=5, NC) --> 31, 32, 40</td></tr>
<tr><td colspan="2">Probability class: Moderate (1/100 - 1/10) Confidence: Moderate</td></tr>
<tr><td>Impact on:
44 - Critical infrastructures' unavailability for an extended period (Harm)</td><td>with the following barriers:
- Increase system's flexibility (E=3, V=5, C) --> 44</td></tr>
<tr><td colspan="2">Related with the following strategic risk(s):
Disruption in the water supply</td></tr>
</table>

<table>
<tr><td rowspan="6">41</td><td>Power / telecommunications outage
Exposure</td></tr>
<tr><td>Power outage may be caused by internal problems in the power supply system or be due to natural capastrophes.</td></tr>
<tr><td>Influenced by:
36 - Very bad weather conditions (Event)
37 - Failure in the suppliers' / contractors' / service (Event)

with the following barriers:
- Stakeholders engagement (E=3, V=3, C) --> 41
- Ready available alternatives (E=5, V=5, C) --> 41, 42</td></tr>
<tr><td>Probability class: Moderate (1/100 - 1/10) Confidence: Moderate
"A major natural catastrophe is due to happen in 50 years".</td></tr>
<tr><td>Impact on:
44 - Critical infrastructures' unavailability for an extended period (Harm)

with the following barriers:
-</td></tr>
<tr><td>Related with the following strategic risk(s):
Disruption in the water supply</td></tr>
</table>

<table>
<tr><td rowspan="6">42</td><td>Unavailability of supply of chemicals, materials, equipment, services
Exposure</td></tr>
<tr><td>The system functionality is highly dependent on the supply of chemicals, materials, equipments and, in some cases, outsourced work force.</td></tr>
<tr><td>Influenced by:
37 - Failure in the suppliers' / contractors' / service (Event)

with the following barriers:
- Ready available alternatives (E=5, V=5, C) --> 42</td></tr>
<tr><td>Probability class: High (1/10 - 1/1) Confidence: High</td></tr>
<tr><td>Impact on:
44 - Critical infrastructures' unavailability for an extended period (Harm)

with the following barriers:
- Increase system's flexibility (E=3, V=5, C) --> 44</td></tr>
<tr><td>Related with the following strategic risk(s):
Disruption in the water supply</td></tr>
</table>

<table>
<tr><td rowspan="6">43</td><td colspan="2">Insufficient human resources to operate the system
Exposure</td></tr>
<tr><td colspan="2">Unavailability of human resources in such a way that water supply system can not be operated, due to to social problems (demonstrations, strikes, etc.) or to pandemic.</td></tr>
<tr><td>Influenced by:
38 - Strikes (Event)
39 - Pandemic (Event)</td><td>with the following barriers:
- Minimum services guaranteed (E=1, V=3, C) --> 43
- Equipment automation (E=3, V=3, NC) --> 43</td></tr>
<tr><td colspan="2">Probability class: Moderate (1/100 -1/10) Confidence: Moderate
Social tension is high, but awareness of EPAL's mission is also high.</td></tr>
<tr><td>Impact on:
44 - Critical infrastructures' unavailability for an extended period (Harm)</td><td>with the following barriers:
-</td></tr>
<tr><td colspan="2">Related with the following strategic risk(s):
Disruption in the water supply</td></tr>
</table>

<table>
<tr><td rowspan="6">44</td><td colspan="2">Critical infrastructures' unavailability for an extended period
Harm</td></tr>
<tr><td colspan="2">Critical assets unavailability for an extended period, due to mechanical, electrical or structural failure, to lack of chemicals to treat water, to lack of people to operate the system, to a power outage or to the presence of contaminated water in the system.</td></tr>
<tr><td>Influenced by:
31 - Reduced water quality / contamination at sources (Exposure)
32 - Reduced water quality / contamination in the Transport or Distribution system (Exposure)
40 - Critical assets' failure (Exposure)
41 - Power / telecommunications outage (Exposure)
42 - Unavailability of supply of chemicals, materials, equipment, services (Exposure)
43 - Insufficient human resources to operate the system (Exposure)</td><td>with the following barriers:
- WTPs' efficiency (E=1, V=1, C) --> 44
- PCQA (E=3, V=n/a, NC) --> 33, 44
- Online monitoring (E=1, V=1, C) --> 33, 44
- Optimal location of disinfection points (E=1, V=1, NC) --> 33, 44
- Sources' diversification (E=1, V=1, NC) --> 44
- Increase system's flexibility (E=3, V=5, C) --> 44</td></tr>
<tr><td colspan="2">Probability class: Moderate (1/100 - 1/10) Confidence: Moderate</td></tr>
<tr><td>Impact on:
(strategic objective)</td><td>with the following barriers:
- Business continuity -contigency plans: knowledge sharing - internal and external; what to do in case of harm - for ex., tele-communications - (E=3, V=5, C).</td></tr>
<tr><td colspan="2">Related with the following strategic risk(s):
Disruption in the water supply</td></tr>
</table>

45	**Water losses increase** *Event*
	Water losses (either in EPAL's system or in the distribution systems of the Municipal Clients) may increase due to ageing of the mains and to insufficient maintenance or renewal practices.
	Influenced by: n/a with the following barriers: n/a
	Probability class: **Low (1/1000 - 1/100)** *Confidence: High*
	Impact on: 50 - Increase in the demand (Exposure) with the following barriers: - Active leakage control (E=1, V=1, NC) --> 50 - Sensibilization campaign (E=4, V=n/a, NC) --> 50
	Related with the following strategic risk(s): Lack of adequate Water Quantity supplied

46	**Consumption increase** *Event*
	Consumption may increase due to an increase in population or in economic activity
	Influenced by: n/a with the following barriers: n/a
	Probability class: **Very Low (1/10000 - 1/1000)** *Confidence: High*
	Impact on: 50 - Increase in the demand (Exposure) with the following barriers: - Scarcity tariffs (E=4, V=5, NC) --> 50 - Sensibilization campaigns (E=4, V=n/a, NC) --> 50
	Related with the following strategic risk(s): Lack of adequate Water Quantity supplied

47	**Droughts / Capture in Spain** *Event*	
	Occurence of severe or extreme droughts, which may lead to retention of water in the Spanish basin of Tagus River	
	Influenced by: n/a	with the following barriers: n/a
	Probability class: **Low (1/1000 - 1/100)** *Confidence: High* Adaptaclima project foresees that extreme droughts will occur within the next 20 years, but C. Bode reservoir is very resilient and it will not happen during this hydrological year.	
	Impact on: 51 - Reduced water availability at sources (Exposure)	with the following barriers: -
	Related with the following strategic risk(s): Lack of adequate Water Quantity supplied	

48	**High power generation or major works at C.Bode** *Event*	
	C.Bode reservoir is shared with EDP that uses it for electricity production. If the turbination lowers the water level below EPAL's intakes, EPAL will not be able to abstract water from that source.	
	Influenced by: n/a	with the following barriers: n/a
	Probability class: **Low (1/1000 - 1/100)** *Confidence: High* It is safeguarded in EDP's concession contract with APA that they cannot turbinate below a level that compromises EPAL.	
	Impact on: 51 - Reduced water availability at sources (Exposure)	with the following barriers: - Relation with EDP (E=3, V=5, C) --> 51 - C.Bode reservoir management commission (E=3, V=5, C) --> 51
	Related with the following strategic risk(s): Lack of adequate Water Quantity supplied	

<table>
<tr><td rowspan="6">50</td><td>Increase in the demand
Exposure</td></tr>
<tr><td>Increase in the demand (by actual clients) result from an effective increase in consumption and/or an increase in water losses</td></tr>
<tr><td>Influenced by:
45 - Water losses increase (Event)
46 - Consumption increase (Event)

with the following barriers:
- Scarcity tariffs (E=4, V=5, NC) --> 50
- Sensibilization campaigns (E=4, V=n/a, NC) --> 50
- Active leakage control (E=1, V=1, NC) --> 50</td></tr>
<tr><td>Probability class: Very Low (1/10000 - 1/1000) Confidence: High</td></tr>
<tr><td>Impact on:
53 - Supply/Demand balance in deficit (Harm)

with the following barriers:
-</td></tr>
<tr><td>Related with the following strategic risk(s):
Lack of adequate Water Quantity supplied</td></tr>
</table>

<table>
<tr><td rowspan="6">51</td><td>Reduced water availability at sources
Exposure</td></tr>
<tr><td>Water availability at sources is reduced due to the occurence of droughts or, for C.Bode, problems at the dam/high turbination.</td></tr>
<tr><td>Influenced by:
47 - Droughts / Capture in Spain (Event)
48 - High power generation or major works at C.Bode (Event)

with the following barriers:
- Relation with EDP (E=3, V=5, C) --> 51
- C.Bode reservoir management commission (E=3, V=5, C) --> 51</td></tr>
<tr><td>Probability class: Low (1/1000 - 1/100) Confidence: High
Adaptaclima project foresees that extreme droughts will occur within the next 20 years, but C. Bode reservoir is very resilient and it will not happen during this hydrological year.It is safeguarded in EDP's concession contract with APA that they cannot turbinate below a level that compromises EPAL.</td></tr>
<tr><td>Impact on:
53 - Supply/Demand balance in deficit (Harm)

with the following barriers:
- Sources' diversification (E=2, V=3, C) --> 53</td></tr>
<tr><td>Related with the following strategic risk(s):
Lack of adequate Water Quantity supplied</td></tr>
</table>

<table>
<tr><td rowspan="6">49</td><td colspan="2">Undercapacity of the assets
Exposure</td></tr>
<tr><td colspan="2">Assets are underdesigned for the actual demand</td></tr>
<tr><td>Influenced by:
3 - Inadequate long-term planning (Event)</td><td>with the following barriers:
- Periodic review (E=1, V=1, NC) --> 8, 21, 49</td></tr>
<tr><td colspan="2">Probability class: Very Low to Low (1/10000 - 1/100) Confidence: High</td></tr>
<tr><td>Impact on:
52 - Water doesn't flow from sources to the delivery points (Harm)</td><td>with the following barriers:
-</td></tr>
<tr><td colspan="2">Related with the following strategic risk(s):
Lack of adequate Water Quantity supplied</td></tr>
</table>

<table>
<tr><td rowspan="6">52</td><td colspan="2">Water doesn't flow from sources to the delivery points
Harm</td></tr>
<tr><td colspan="2">Assets are functioning but are not able to deliver the total demanded flow because of their undercapacity</td></tr>
<tr><td>Influenced by:
49 - Undercapacity of the assets (Exposure)</td><td>with the following barriers:</td></tr>
<tr><td colspan="2">Probability class: Very Low (1/10000 - 1/1000) Confidence: High</td></tr>
<tr><td>Impact on:
(strategic objective)</td><td>with the following barriers:
- Business continuity (contigency plans)</td></tr>
<tr><td colspan="2">Related with the following strategic risk(s):
Lack of adequate Water Quantity supplied</td></tr>
</table>

<table>
<tr><td rowspan="6">53</td><td colspan="2">Supply/Demand balance in deficit
Harm</td></tr>
<tr><td colspan="2">The demand for water exceeds the availability at sources.</td></tr>
<tr><td>Influenced by:
50 - Increase in the demand (Exposure)
51 - Reduced water availability at sources (Exposure)</td><td>with the following barriers:
- Sources' diversification (E=2, V=3, C) --> 53</td></tr>
<tr><td colspan="2">Probability class: Low (1/1000 - 1/100) Confidence: High</td></tr>
<tr><td>Impact on:
(strategic objective)</td><td>with the following barriers:
- Business continuity (contigency plans)</td></tr>
<tr><td colspan="2">Related with the following strategic risk(s):
Lack of adequate Water Quantity supplied</td></tr>
</table>

<table>
<tr><td rowspan="6">54</td><td colspan="2">Pipe bursts in Lisbon network (abbrev.)
Event</td></tr>
<tr><td colspan="2">Pipe bursts occur every week in the distribution system. This can cause "brown water" to flow from taps (after the repair) and, in some cases, damages to private properties. Organoleptic issues may also arise from the operation conditions (low flow velocities).</td></tr>
<tr><td>Influenced by:
n/a</td><td>with the following barriers:</td></tr>
<tr><td colspan="2">Probability class: Certain (1/1) Confidence: High</td></tr>
<tr><td>Impact on:
58 - Non compliance of organoleptic parameters (Exposure)
59 - 3rd parties injured (Exposure)</td><td>with the following barriers:
- AM best practices (E=1, V=5, NC) --> 58, 59</td></tr>
<tr><td colspan="2">Related with the following strategic risk(s):
Reputation and trust compromised</td></tr>
</table>

55	**Fraud, non-compliance with Ethic Code** *Event*
	Fraud or other actions that do not comply with EPAL's ethic code.
	Influenced by: n/a — with the following barriers:
	Probability class: **Low (1/1000 - 1/100)** *Confidence: Moderate* The mechanisms to avoid non-compliances with Ethic Code exist.
	Impact on: 59 - 3rd parties injured (Exposure) — with the following barriers: - Fighting corruption plan (E=2, V=3, NC) --> 59
	Related with the following strategic risk(s): Reputation and trust compromised

56	**Health and Safety of employees compromised** *Event*
	Employees may be seriously injured (or killed) during their working activities.
	Influenced by: n/a — with the following barriers: n/a
	Probability class: **Moderate (1/100 - 1/10)** *Confidence: Moderate*
	Impact on: 59 - 3rd parties injured (Exposure) — with the following barriers: - Health and Safety System (E=2, V=5, NC) --> 59
	Related with the following strategic risk(s): Reputation and trust compromised

<table>
<tr><td rowspan="6">57</td><td colspan="2">Inadequate relationship with Unions / Media / Stakeholders
Event</td></tr>
<tr><td colspan="2">An inadequate relationship with Unions/Media/Stakeholders may lead to an increse in the release of defaming news.</td></tr>
<tr><td>Influenced by:
n/a</td><td>with the following barriers:
n/a</td></tr>
<tr><td colspan="2">Probability class: Moderate (1/100 - 1/10) Confidence: High
It has happened in the past.</td></tr>
<tr><td>Impact on:
60 - Power to influence public opinion (Exposure)</td><td>with the following barriers:
- Stakeholders consultation
(E=2, V=1, NC) --> 60
- Workers relationship policy
(E=1, V=5, NC) --> 60
- Media relationship
(E=1, V=1, C) --> 60
- Communication consultation
(E=1, V=1, NC) --> 60</td></tr>
<tr><td colspan="2">Related with the following strategic risk(s):
Reputation and trust compromised</td></tr>
</table>

<table>
<tr><td rowspan="6">58</td><td colspan="2">Non compliance of organoleptic parameters
Exposure</td></tr>
<tr><td colspan="2">Organoleptic parameters (colour, smell, taste) may be beyond the required level.</td></tr>
<tr><td>Influenced by:
54 - Pipe bursts in Lisbon network (abbrev.) (Event)</td><td>with the following barriers:
- AM best practices (E=1, V=5, NC) --> 58, 59</td></tr>
<tr><td colspan="2">Probability class: Low (1/1000 - 1/100) Confidence: High
Number of claims is low.</td></tr>
<tr><td>Impact on:
61 - Public opinion damage (Harm)</td><td>with the following barriers:
- Information to the customers (E=3, V=n/a, NC) --> 61</td></tr>
<tr><td colspan="2">Related with the following strategic risk(s):
Reputation and trust compromised</td></tr>
</table>

59	**3rd parties injured** *Exposure*
	3rd parties may be injured due to the occurence of pipe bursts, non-compliance with ethical code or health and safety failure.
	Influenced by: 54 - Pipe bursts in Lisbon network (abbrev.) (Event) 55 - Fraud, non-compliance with Ethic Code (Event) 56 - Health and Safety of employees compromised (Event) with the following barriers: - AM best practices (E=1, V=5, NC) --> 58, 59
	Probability class: **Moderate (1/100 - 1/10)** *Confidence: High* Mainly due to pipe bursts in Lisbon.
	Impact on: 61 - Public opinion damage (Harm) with the following barriers: - Adequate compensation policy (E=1, V=n/a, NC) --> 61 - Re-enforcement of positive image (E=2, V=3, C) --> 61
	Related with the following strategic risk(s): Reputation and trust compromised

60	**Negative influence on public opinion** *Exposure*
	Unions, media and stakeholders have the power to influence public opinion, through the release of defaming news.
	Influenced by: 57 - Inadequate relationship with Unions / Media / Stakeholders (Event) with the following barriers: - Stakeholders consultation (E=2, V=1, NC) --> 60 - Workers relationship policy (E=1, V=5, NC) --> 60 - Media relationship (E=1, V=1, C) --> 60 - Communication consultation (E=1, V=1, NC) --> 60
	Probability class: **Moderate (1/100 – 1/10)** *Confidence: High* This refers to the strenght of the exposure (vulnerability).
	Impact on: 61 - Public opinion damage (Harm) with the following barriers: - Re-enforcement of positive image (E=2, V=3, C) --> 61
	Related with the following strategic risk(s): Reputation and trust compromised

<table>
<tr><td rowspan="6">61</td><td colspan="2">Public opinion damage
Harm</td></tr>
<tr><td colspan="2">A damage in public opinion may arise from "direct causes" (non-compliance with organolectic parameters, 3rd parties injured, inadequate relationship with syndicates and media) or "indirect causes" (failure to achieve each of the other strategic objectives).</td></tr>
<tr><td>Influenced by:
60 - Power to influence public opinion (Exposure)
59 - 3rd parties injured (Exposure)
58 - Non compliance of organoleptic parameters (Exposure)</td><td>with the following barriers:
- Adequate compensation policy (E=1, V=n/a, NC) --> 61
- Information to the customers (E=3, V=n/a, NC) --> 61
- Re-enforcement of positive image (E=2, V=3, C) --> 61</td></tr>
<tr><td colspan="2">Probability class: Moderate (1/100 - 1/10) Confidence: Moderate
The range is due to the contribution of both "direct" and "indirect causes".</td></tr>
<tr><td>Impact on:
(strategic objective)</td><td>with the following barriers:
- Re-enforcement of positive image (contingency plans)</td></tr>
<tr><td colspan="2">Related with the following strategic risk(s):
Reputation and trust compromised</td></tr>
</table>

<table>
<tr><td rowspan="6">100</td><td colspan="2">Inadequate governance
Risk factor</td></tr>
<tr><td colspan="2">Inadequate governance may be due to and excessive interference of the Government in EPAL's management. It has effects on the image (identification of EPAL with the image of the public sector in general), on the approval of investments, on the salaries and EPAL's capacity to capture talent, etc. (Profitability), etc.</td></tr>
<tr><td>Influenced by:</td><td>with the following barriers:</td></tr>
<tr><td colspan="2">Probability class: Moderate (1/100 - 1/10) Confidence: High</td></tr>
<tr><td>Impact on:</td><td>with the following barriers:</td></tr>
<tr><td colspan="2">Related with the following strategic risk(s):</td></tr>
</table>

<table>
<tr><td rowspan="6">101</td><td>Lack of communication
Risk factor</td></tr>
<tr><td>Lack of communication between people (especially from different departments) may lead to several inefficiencies in the processes. It affects profitability (unoptimized working processes) and may affect the disruption in the supply or the health and safety of employees.</td></tr>
<tr><td>Influenced by: with the following barriers:</td></tr>
<tr><td>Probability class: Certain (1/1) Confidence: High</td></tr>
<tr><td>Impact on: with the following barriers:</td></tr>
<tr><td>Related with the following strategic risk(s):</td></tr>
</table>

<table>
<tr><td rowspan="6">102</td><td>Poor HR practices
Risk factor</td></tr>
<tr><td>Poor HR practices result from difficulties in capturing talent to the company; in ensuring that knowledge transfer is made when employees get retired or move to another company; and also in renewing "minds" in the company ("familiar dynasties"). This directly affects AM practices.
NOTE: >200 / 700 employees are aged 55+</td></tr>
<tr><td>Influenced by: with the following barriers:</td></tr>
<tr><td>Probability class: Certain (1/1) Confidence: High</td></tr>
<tr><td>Impact on: with the following barriers:</td></tr>
<tr><td>Related with the following strategic risk(s):</td></tr>
</table>

<table>
<tr><td rowspan="6">103</td><td>Legal non-compliance
Risk factor</td></tr>
<tr><td>Non-compliance with current legislation. It affects reputation and trust.</td></tr>
<tr><td>Influenced by: with the following barriers:</td></tr>
<tr><td>Probability class: Moderate (1/100 - 1/10) Confidence: High</td></tr>
<tr><td>Impact on: with the following barriers:</td></tr>
<tr><td>Related with the following strategic risk(s):</td></tr>
</table>

<table>
<tr><td rowspan="7">104</td><td colspan="2">Inadequate data/information
Risk factor</td></tr>
<tr><td colspan="2">Inadequate data or information about the different subjects of the company - namely the assets - leads to an increase in the innefficiency of the processes and to bad decision-making (affects Profitability).</td></tr>
<tr><td>Influenced by:</td><td>with the following barriers:</td></tr>
<tr><td>Probability class: High (1/10 - 1/1)</td><td>Confidence: High</td></tr>
<tr><td>Impact on:</td><td>with the following barriers:</td></tr>
<tr><td colspan="2">Related with the following strategic risk(s):</td></tr>
</table>

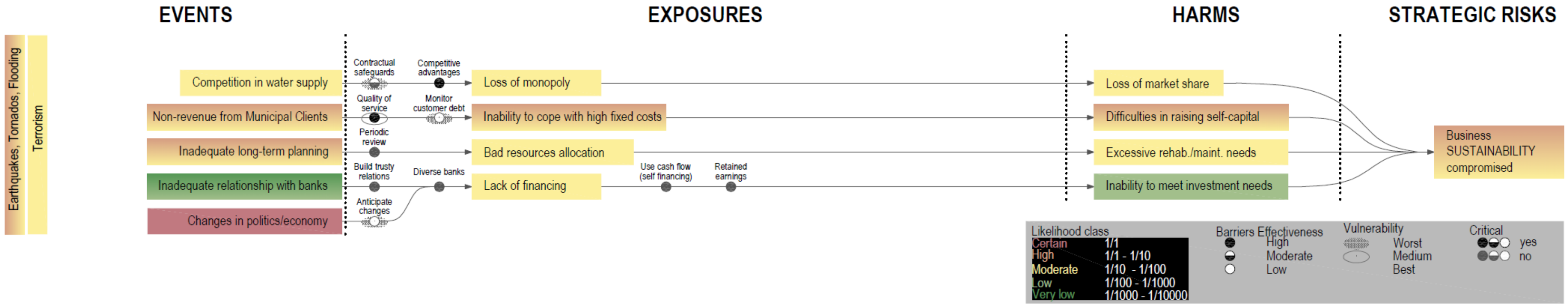
2. NARRATIVES

1| STRATEGIC OBJECTIVE

To guarantee economic and financial Business Sustainability in the long-term.

2| LIKELIHOOD OF NOT MEETING THE STRATEGIC OBJECTIVE

Events / Exposures / Harms Likelihoods



Business sustainability has a moderate-to-high likelihood of being compromised, mainly due to difficulties in raising self-capital. This results from the inability to cope with high fixed costs in case municipal clients stop paying for the water, which has a moderate-to-high likelihood to happen either because they cannot afford it (due to the economic crisis the country is facing) or because they do not want to (litigations)[1]. This strategic objective may be also affected by a loss of market share, if municipal clients produce their own water[2], or by the excessive need to proceed with capital or operational expenditures, though these harms have a moderate likelihood of occurrence, because clients still rely on EPAL to cover their needs and long–term planning is improving. Even more unlikely to happen, is the inability to meet investment needs, due to lack of financing, since EPAL can use its cash flow or retain earnings. Lack of external financing may occur due to an inadequate relationship with banks or to changes in politics/economy[3]; notwithstanding, the relation of EPAL with EIB is very strong, and it acts as a highly efficient "barrier".

Existing barriers – Efficacy, Criticality and Vulnerability

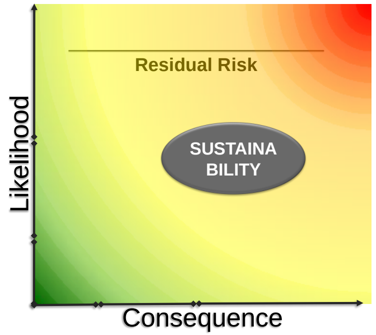
Most barriers reveal to be highly effective: the competitive advantages of EPAL (its history, location, scale), the quality of the service provided, the periodic review of the long-term plan, the trusty relationships with banks, the diversification of banks as sources of financing as well as self-financing and retaining earnings from the shareholder. The three latter barriers contribute to lower the likelihood of "inability to meet investment needs", in spite of the higher likelihood associated to the respective events and exposure. Contractual safeguards is a medium effective barrier, since it applies to a limited number of municipal clients. Monitoring customer debts and trying to anticipate changes in politics or economy are low effective barriers. The most critical barriers are the competitive advantages of the company as well as the quality of service. The most vulnerable ones are contractual safeguards (litigation processes are lagging), customer debts' monitoring (it is not preventative) and anticipating changes (there are no mechanisms implemented in the company with that aim).

3| CONSEQUENCES OF NOT MEETING THE STRATEGIC OBJECTIVE

Catastrophic:	The company **will not be able** to accomplish its mission in the **next 10 years**
Very bad:	The company **will not be able** to accomplish its mission in the **next 20 years**
Bad:	The company **will be able** to accomplish its mission in the **next 20 years** but struggling with **high economic or financial constraints**
Moderate:	The company **will be able** to accomplish its mission in the **next 20 years** with **moderate economic or financial constraints**
Minor:	The company **will be able** to accomplish its mission in the **next 20 years** with **minor economic or financial constraints**

The company will be able to accomplish its mission in the next 20 years but struggling with high economic or financial constraints. This is a Bad consequence of a hypothetical lack of financing, difficulties in raising self-capital and of the uncertainty in the sector.

4| STRATEGIC RISK



EPAL is a centenary water supply company, which is already a proof of its resilience. Nonetheless, four harms were identified as a potential threat to business sustainability: loss of market share, difficulties in raising self-capital, excessive rehabilitation or maintenance needs and inability to meet investment needs. Despite of EPAL's capability of self-financing and the competitive advantages, including the quality of the service provided, there is a moderate to high likelihood that the company will struggle with high economic or financial constraints in accomplishing its mission in the next 20 years, especially due to the difficulties in raising self-capital.

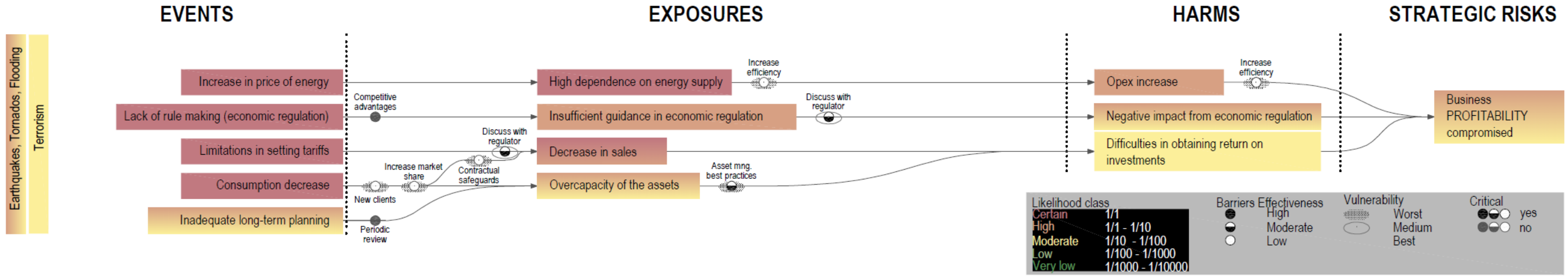
[1] It already happened in one municipality.
[2] It happens partially in some municipalities.
[3] For example, in 2011 the economic situation of the country led the European Investment Bank (EIB) to postpone the process of financing EPAL's investments.

1| STRATEGIC OBJECTIVE

To guarantee adequate levels of Business Profitability, each year.

2| LIKELIHOOD OF NOT MEETING THE STRATEGIC OBJECTIVE

Events / Exposures / Harms Likelihoods



<u>Business profitability has a moderate-to-high likelihood of being compromised</u>, mainly due to a potential increase in the operational expenditure (Opex), resulting from the increase in the price of energy[1] conjugated with a high dependence on energy to operate the system[2]. The accomplishment of this strategic objective may also be affected by a negative impact from economic regulation, which derives from an insufficient guidance from the regulator. There is a moderate likelihood that difficulties in obtaining return on investments may compromise business profitability, due to the decrease in sales and to the overcapacity of the assets, which were designed to supply higher levels of demand.

Existing barriers – Efficacy, Criticality and Vulnerability

Existing barriers present different degrees of efficacy, being the <u>most effective</u> ones EPAL's competitive advantages (history, location and scale) and the periodic review of long-term plans. Establishing contractual safeguards is not very effective, at present, because these only exist for a minority of the municipal clients. <u>Critical barriers</u> are asset management best practices, in order to overcome potential problems related with the overcapacity of the assets, and discussions with the regulators about the economic regulation guidance, so that a negative impact from regulation may be minimized. The most vulnerable barriers are: increasing market share and finding new clients, since foreseen changes in the sector will make this more difficult to happen; reinforcing contractual safeguards, because it does not depend only on EPAL; increase energy efficiency, since a lot has already been done in this domain and financial constraints are preventing new actions to be implemented; and, finally, implementing asset management best practices, due to urgent need to renew the human capital of EPAL, which is now restricted by law.

3| CONSEQUENCES OF NOT MEETING THE STRATEGIC OBJECTIVE

Very bad :	The company will be in **deficit**
Bad :	The company will **decrease its profits by more than 75%** up to 100%
Moderate :	The company will d**ecrease its profits by more than 25% and less than 75%**
Minor :	The company will **decrease its profits by less than 25%**

The company will decrease its profits by more than 25% and less than 75% (representing 10 to 30 million euros, approximately). This is a Moderate consequence of the increase in the price of energy, or the negative impact from regulation or from the difficulties in obtaining return from the investments.

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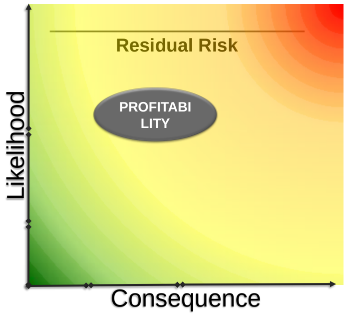
4| STRATEGIC RISK



EPAL is a profitable organization, generating profits of around 40 million euros a year. These profits are intended to remunerate the shareholder as well as the invested capital. With operational costs likely to increase, mainly due to energy costs, and given the limitations in setting the tariffs as well as the decrease in the consumption, there is a moderate-to-high likelihood of this objective being compromised in such a way that the company will decrease its profits by more than 25% and less than 75%.

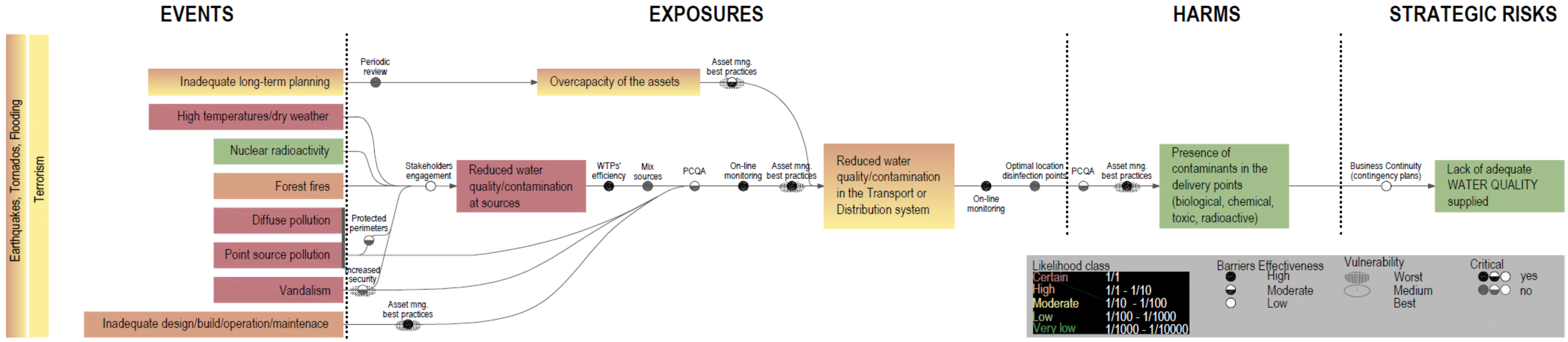
[1] Energy is the highest operational cost of the company, and its price has been increasing over the last years (Annual Accounts Report, 2011).
[2] The water supply system of EPAL is designed in such a way that energy is needed not only to abstract water from all of the current sources (superficial and underground) but also to deliver it to the customers.
[3] For example, in 2011 the economic situation of the country led the European Investment Bank (EIB) to postpone the process of financing EPAL's investments.

1| STRATEGIC OBJECTIVE

To supply water with such Quality that it will not harm customers' health.

2| LIKELIHOOD OF NOT MEETING THE STRATEGIC OBJECTIVE

Events / Exposures / Harms Likelihoods



Water quality is compromised from the sources: high temperatures in dry weather lead to the occurrence of *algal blooms*[1], and treated or untreated wastewater discharges, as well as agriculture, mine[2] and quarries run-off occur in the watershed. Forest fires haven't affected water quality in the abstraction points[3], despite their yearly occurrence in the surroundings of Castelo do Bode reservoir. However, in the coming years their magnitude may change for worst. Some of EPAL's premises have been subject to vandalism, which might, as well, put in danger the water quality. Terrorism actions or natural catastrophes such as earthquakes are less likely to happen. With a rare likelihood of occurrence there is the possibility of failure in the nuclear power plant in Almaraz, or a *cryptosporidium* outbreak. Along the distribution system contamination may occur due to point source or diffuse pollution, but that has not been happening[4]. Contamination may also be due to inadequate actions in the WTP or during maintenance activity – although the likelihood for this to happen is low, it might increase in the future, since a significant part of the employees is about to retire[5] and it is difficult to guarantee knowledge transfer. Water quality may also get worse due to the low flow velocities in the mains[6], which is derived from their overcapacity.

Existing barriers – Efficacy, Criticality and Vulnerability

The most effective barriers are: Water Treatment Plants, Chlorination Points, Mixing Water from different sources, On-line monitoring and Asset Management Best Practices (selection of materials, construction methodologies, preparedness of the teams, washing and disinfection of water tanks, compliance with health and safety code). Laboratory analysis of water samples (PCQA), the existence of Protected Zones around water sources and increase of Security measures in EPAL's premises reveal to be medium effective barriers. Watershed stakeholders engagement appears to be a low effective barrier. The most critical barriers are Water Treatment Plants, On-line monitoring and Asset Management Best Practices. The latter is also the most vulnerable one, given the fact that a significant part of the employees is about to retire[5] and it is difficult to guarantee knowledge transfer.

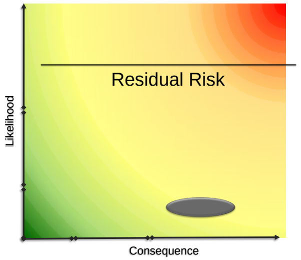
3| CONSEQUENCES OF NOT MEETING THE STRATEGIC OBJECTIVE

Catastrophic:	**50 or more** customers will present **non-reversible health problems**, including the **possibility of death**
Very bad:	**Less than 50** customers will present **non-reversible health problems**, including the **possibility of death OR more than 5000** customers will present **reversible health problems**
Bad:	**Less than 5000** and **more than 500** customers will present **reversible health problems**
Moderate:	**Less than 500** and **more than 50** customers will present **reversible health problems**
Minor:	**Less than 50** customers will present **reversible health problems**

The impact on human health of supplying water with biological, chemical or radioactive contaminants depends on the number of people potentially affected and on the reversibility of the diseases. For some rare events (ex.: *cryptosporidium* outburst), the associated consequences may be **Catastrophic**: more than 50 people may have irreversible health problems, including death. However, for the events and their respective exposures identified, the associated consequences may be **Bad**: between 500 and 5000 people may present reversible health problems. The existing Contingency Plans are not effective in case harms with bad to catastrophic consequences occur in the system.

4| STRATEGIC RISK

Quality of the water supplied depends mainly on the raw water quality and on the Water Treatment Plants efficacy. Along the distribution system contamination may also occur, so monitoring (*on-line* and in lab) and chlorination assume a very important role. Mixing water from different sources and different trunk mains contributes to risk reduction, as well. Analytical results show that despite raw water quality being bad (especially in Valada-Tejo), the degree of compliance with legal parameters in terms of the supplied Water Quality is of 99,50%[7], which outlines the importance of the existing barriers for the fulfilment of the strategic objective. The system is not prepared, however, to deal with the consequences of rare events such as *crypto* or *giardia* outbursts or terrorism actions, which would be catastrophic.



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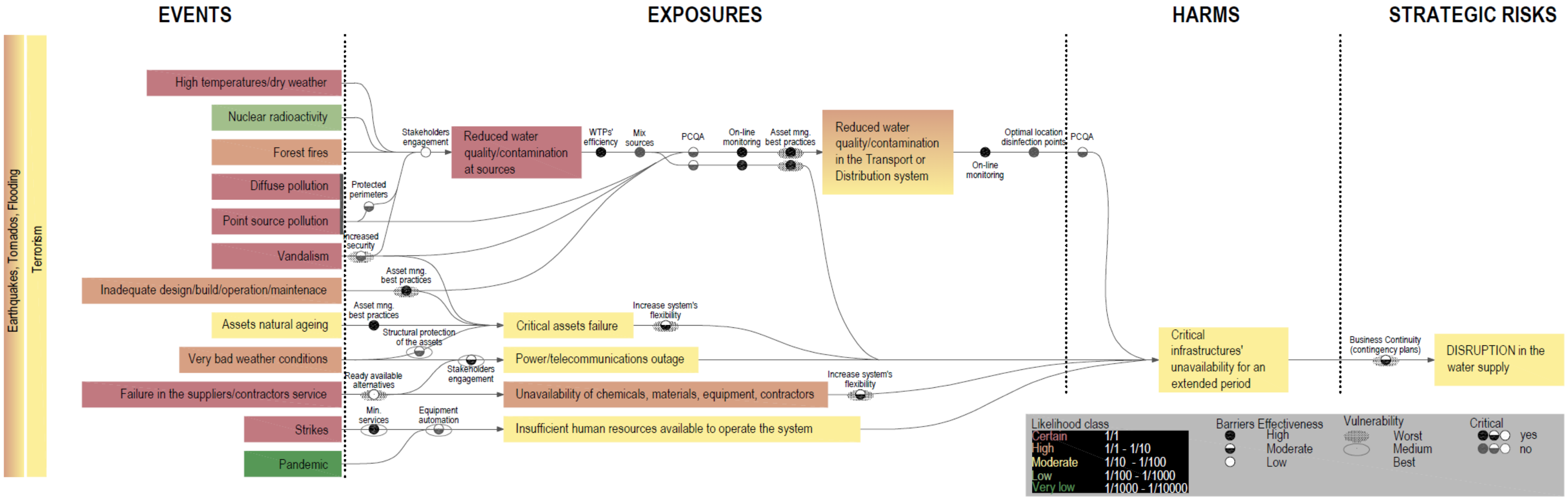
[1] This phenomenon has occurred every year in Valada-Tejo and in the summer of 2012 it lasted for more than 12 weeks, leading to the abandon of this source during that period.
[2] According to the "Minas da Panasqueira study", 2012, these pose no danger for the water quality in Castelo do Bode.
[3] Data from LAB.
[4] Even in the case of free surface aqueducts, like Alviela (in a very bad condition) and Tejo, laboratory analysis of the water showed that, in the last years, the legal parameters are being complied with.
[5] More than 200 out of the 740 employees of EPAL are aged 55 years or more.
[6] Average flow velocities in Lisbon distribution system is 0.09 m/s, according to the hydraulic simulation model of the network.
[7] Annual activities and accounts report, 2011.

1| STRATEGIC OBJECTIVE

To supply water with such Reliability that there are no major disruptions (regardless of the water quantity and quality).

2| LIKELIHOOD OF NOT MEETING THE STRATEGIC OBJECTIVE

Events / Exposures / Harms Likelihoods



<u>Major disruptions in the water supply have a moderate likelihood of occurrence</u>, due to the unavailability of critical infrastructures for an extended period. This can be caused by a large number of interconnected events, which, despite being very likely to happen, have already barriers along the pathway that lower the likelihood of this harm. Besides the more intuitive events that can lead to this harm – assets natural ageing[1], bad weather conditions[2], failure in the supply chain[3] and strikes[4] as well as pandemia, terrorism or natural catastrophes -, unavailability of critical infrastructures may also be caused by water quality problems.

Existing barriers – Efficacy, Criticality and Vulnerability

The <u>most effective</u> and, simultaneously, <u>most critical</u> barriers are: asset management best practices, in a context of assets ageing, and the capability of requesting minimum services in case of strikes; and also all the barriers that lower the likelihood of having a reduced water quality in the distribution system, like Water Treatment Plants, Mixing Water from different sources, On-line monitoring and Asset Management Best Practices. Laboratory analysis of water samples (PCQA), the existence of Protected Zones around water sources and increase of Security measures in EPAL's premises reveal to be medium effective barriers, just like the equipment automation, the contractors' engagement, the increase of the flexibility of the system and the structural protection of the assets against bad weather and vandalism. Watershed stakeholders' engagement and having ready-available alternatives to cope with failures in the supply chain are low effective barriers. Some of these are considered critical barriers, though they are not fully effective. The most vulnerable barriers are the asset management best practices, given the fact that a significant part of the employees is about to retire[5] and the difficulty to guarantee knowledge transfer; the ready available alternatives and the increase in system's flexibility, due to financial constraints; and the increased security, because it is very difficult to protect against vandalism such a large and disperse infrastructural system as EPAL's. Contingency plans are critical, but they are moderately effective, since they are not fully implemented yet, and are highly vulnerable, because they depend on other entities.

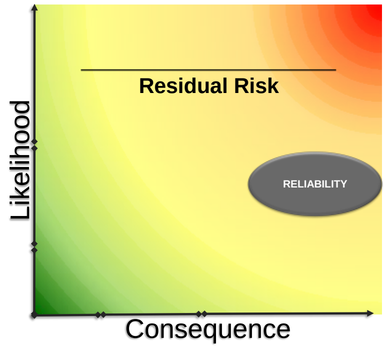
3| CONSEQUENCES OF NOT MEETING THE STRATEGIC OBJECTIVE

Catastrophic:	**2,0 million or more** customers **will not be supplied** at all during 4 days or more
Very bad:	**0,1-2,0 million** customers **will not be supplied** at all **OR 2,0 million or more** customers **will be partially supplied** during 4 days or more
Bad:	**0,1 million or less** customers **will not be supplied** at all **OR 0,5-2,0 million** customers **will be partially supplied** during 4 days or more
Moderate:	**0,1-0,5 million** customers **will be partially supplied** during 4 days or more
Minor:	**0,1 million or less** customers **will be partially supplied** during 4 days or more

The impact of the unavailability of critical assets depends on the number of people potentially affected (without full or partial supply) and on the duration of the period. Taking into account the specific configuration of EPAL' s system and, on the other hand, the nature of the events that may affect the accomplishment of this strategic objective, the associated consequences may be **Catastrophic**: 2,0 million or more customers may not be supplied at all during 4 days or more, due to a natural catastrophe or to a failure of a critical asset.

4| STRATEGIC RISK

Reliability of supply depends on factors that the utility both can and cannot control. Asset management best practices help preventing major failures from occurring, and adequate human resources and suppliers' relationships help in dealing with strikes or supply chain failures, respectively. Nonetheless, reinforcing the assets against vandalism or bad weather conditions are not very effective barriers. Critical assets may also become unavailable due to water quality issues, in case of contamination. Although the likelihood of occurrence of a major disruption in the supply is moderate, the respective consequences may be catastrophic, with impact on more than 2 million people.



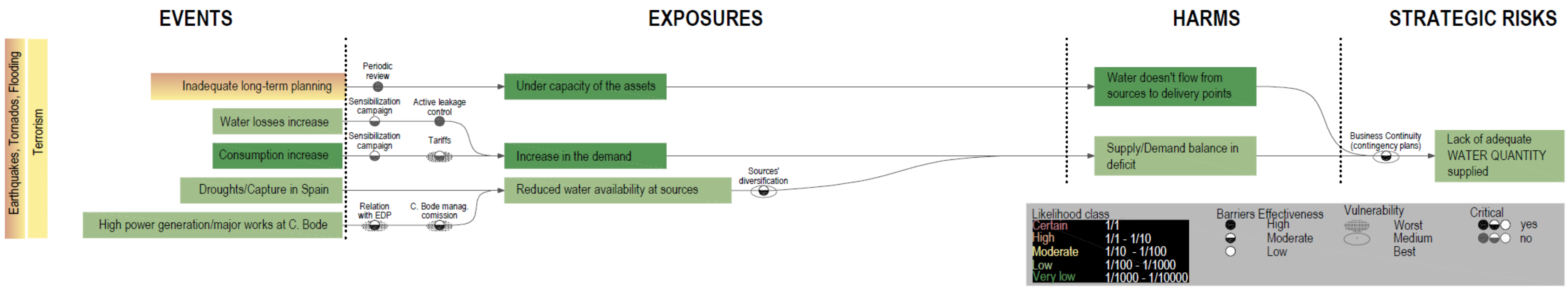
1 The sub-system responsible for the delivery of approx.90% of the water is already 25 years old, and is now beginning to present its first failures.
2 In recent years, some sites of EPAL were hit by mini-tornados, and some assets were destroyed.
3 Suppliers/contractors may fail to meet agreed service due to economic, social or other reasons. EPAL has already experienced contractor's bankruptcy, due to the actual economic crisis.
For some of the products, there is no stock, and in some cases there is a high dependence on one supplier.
4 Strikes have occurred in the last years and the economic and financial crisis tend to increase its frequency.
5 More than 200 out of the 740 employees of EPAL are aged 55 years or more.

1| STRATEGIC OBJECTIVE

To supply Water in such a Quantity that satisfies the demand needs (regardless its quality or reliability).

2| LIKELIHOOD OF NOT MEETING THE STRATEGIC OBJECTIVE

Events / Exposures / Harms Likelihoods



<u>There is a low likelihood that a lack of adequate water quantity is supplied</u>, either in terms of the supply/demand balance or of the capacity of production and transport of the water supply system. On the one hand, there is no shortage of water expected to occur in the next 18 months (period of analysis), since C. Bode reservoir has enough capacity to deal with a drought if it occurred in the next year. On the other hand, the consumption maintains its decreasing trend, and water losses are kept under control. Moreover, there are no constraints in terms of the system's capacity, since it is designed for past consumption thresholds, which are, by far, higher than the ones in the present.

Existing barriers – Efficacy, Criticality and Vulnerability

Existing barriers are <u>mostly moderately effective</u>, namely sensibilization campaigns[1] and application of water scarcity tariffs to reduce demand, as well as reinforcing the relationship with the electrical company, EDP[2] and the participation in the C. Bode reservoir management commission, in order to prevent the reduction of available water in the reservoir. The latter are considered to be <u>the most critical</u> barriers to manage this strategic objective, along with the diversification of water sources. Most barriers are <u>medium to high vulnerable</u>, since their implementation does not depend fully on EPAL, and the counter parties might not be willing to cooperate.

3| CONSEQUENCES OF NOT MEETING THE STRATEGIC OBJECTIVE

Catastrophic:	**50% or more** of the daily average flow will not be supplied during **6 months or more**
Very bad:	**50% or more** of the daily average flow will not be supplied during **1-6 months**
Bad:	**25%-50%** of the daily average flow will not be supplied during **6 months or more**
Moderate:	**25%-50%** of the daily average flow will not be supplied during **1-6 months**
Minor:	**Less than 25%** of the daily average flow will not be supplied during **more than 1 month**

If water availability at sources is reduced due to the occurence of extreme droughts in successive years or to problems at C. Bode dam or reservoir (e.g.: high turbination), the consequences will be **Very Bad**, which means that 50% or more of the daily average flow may not be supplied during 1-6 months.

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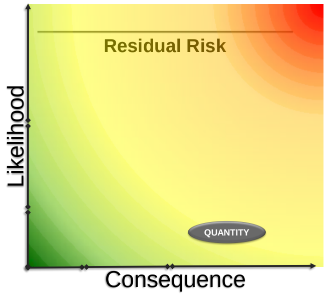
4| STRATEGIC RISK



Supplying adequate water quantity is one core strategic objective of every water supply company. At present, EPAL has a low likelihood of facing shortage of water, due to the decrease in demand, to the available storage at Castelo do Bode reservoir and to the overcapacity of the water production and transportation systems.

As this reservoir is jointly explored with the electricity company, EDP, the relationship between the two utilities emerges as a critical barrier, since the hydropower generation may lower the levels of water in the reservoir in such a way that EPAL's abstraction gets compromised. Although this has never occurred in the past, this issue will be even more critical in periods of drought, which are expected to become more frequent and more severe in the next decades.

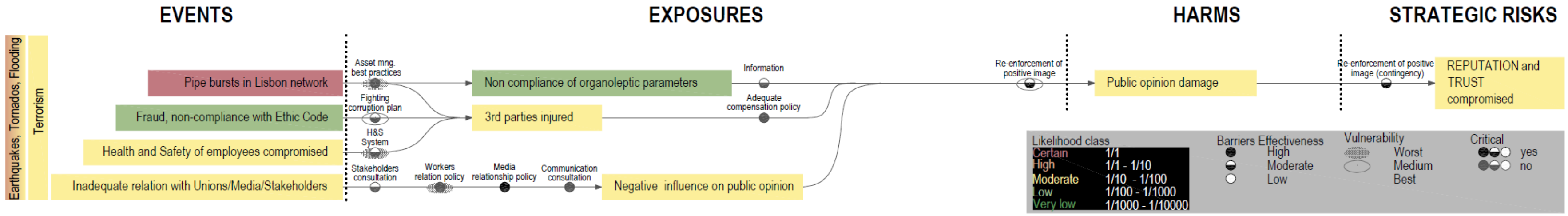
[1] A campaign took place at national level in 2005, when a severe drought occurred. It is considered one of the contributing factors for the decrease in the demand that happened since then.
[2] C.Bode reservoir is shared with EDP that uses it for electricity production. If the turbination lowers the water level below EPAL's intakes, EPAL will not be able to abstract water from that source.

1| STRATEGIC OBJECTIVE

To assure the Trust from the customers, as well as EPAL's Reputation among other national and international water utilities.

2| LIKELIHOOD OF NOT MEETING THE STRATEGIC OBJECTIVE

Events / Exposures / Harms Likelihoods



There is a moderate likelihood that reputation and trust become compromised, due to damages in public opinion. This may result from the non-compliance of organoleptic parameters[1], which may be due to pipe bursts, for example, though there are empirical evidences that it is low likely to happen. It may also be caused by injuries to third parties, as consequence of pipe bursts, fraud[2] or bad practices regarding the health and safety of workers. Unions, media and other stakeholders are very likely to negatively influence public opinion[3], in case the Board does not keep an adequate relation with them. This strategic risk is also very highly dependent on the other strategic risks, namely on the way EPAL deals with the respective harms, should they occur.

Existing barriers – Efficacy, Criticality and Vulnerability

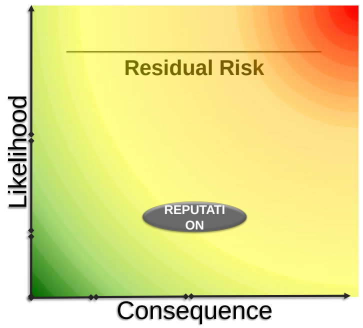
Asset management practices have proven to be highly effective in preventing damages caused by pipe bursts, either relating to injuries to third parties, or to non-compliance of organoleptic parameters. However, this is one of the most vulnerable barriers, mainly due to difficulties in transferring knowledge from aged employees to new ones[4]. The existing plan to fight corruption and the Health and Safety system reveal to be moderately effective barriers, in order to avoid third parties' injuries, and are also vulnerable, due to the same Human Resources issues and to the lack of an effective supervision, respectively. With the aim of building a good relation with unions, media and stakeholders, several barriers are in place, most of which reveal to be highly efficient: stakeholders consultation, set up of a workers relation policy, media relationship policy and using communication consultation. Providing information to the customers about the characteristics of organoleptic parameters and re-enforcing the positive image of the company on a continuous base reveal to be moderately effective barriers, while adopting an adequate compensation policy to injured people has proven to be highly effective in preventing damage in public opinion. Re-enforcing the positive image of the company on a continuous base may also be used as a contingency measure, in case public opinion damage occurs; together with the media relationship policy, these are the most critical barriers.

Very bad :	**One breaking news OR more than one non breaking news** per year defaming the **quality of the water** supplied
Bad :	**One breaking news OR more than one non breaking news** per year related with **3rd parties or H&S injuries**
Moderate :	**One breaking news OR more than one non breaking news** per year defaming the **reliability** of the water supplied
Minor :	**One breaking news OR more than one non breaking news** per year defaming the **governance of the company**

3| CONSEQUENCES OF NOT MEETING THE STRATEGIC OBJECTIVE

The impact of the public opinion damage depends on whether the company is negatively referenced in breaking news or non-breaking news, as well as on the type of issues that are mentioned. Taking into account the afore mentioned issue of human resources ageing, the consequences of not meeting this strategic objective may be considered Bad: one breaking news or more than one non-breaking news per year, related with 3rd parties or H&S injuries.

4| STRATEGIC RISK



EPAL has a good reputation and secures the trust of its customers. However, as Warren Buffett once said, *"It takes 20 years to build a reputation and five minutes to ruin it."*. Reputation and trust is highly dependent of the public opinion, which can be damaged by non-compliance of organoleptic parameters in the water, third parties' injuries or negative influence from unions, media or other stakeholders. In the present situation, there is a moderate likelihood that this strategic objective gets compromised, with bad consequences associated. The most critical barriers are the media relationship policy and the re-enforcement of EPAL's positive image, the latter showing potential to improve in terms of its effectiveness.

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[1] Pipe bursts occur every week in the distribution system. This can cause "brown water" to flow from taps (after the repair) and, in some cases, damages to private properties. Organoleptic issues may also arise from the operation conditions (low flow velocities).

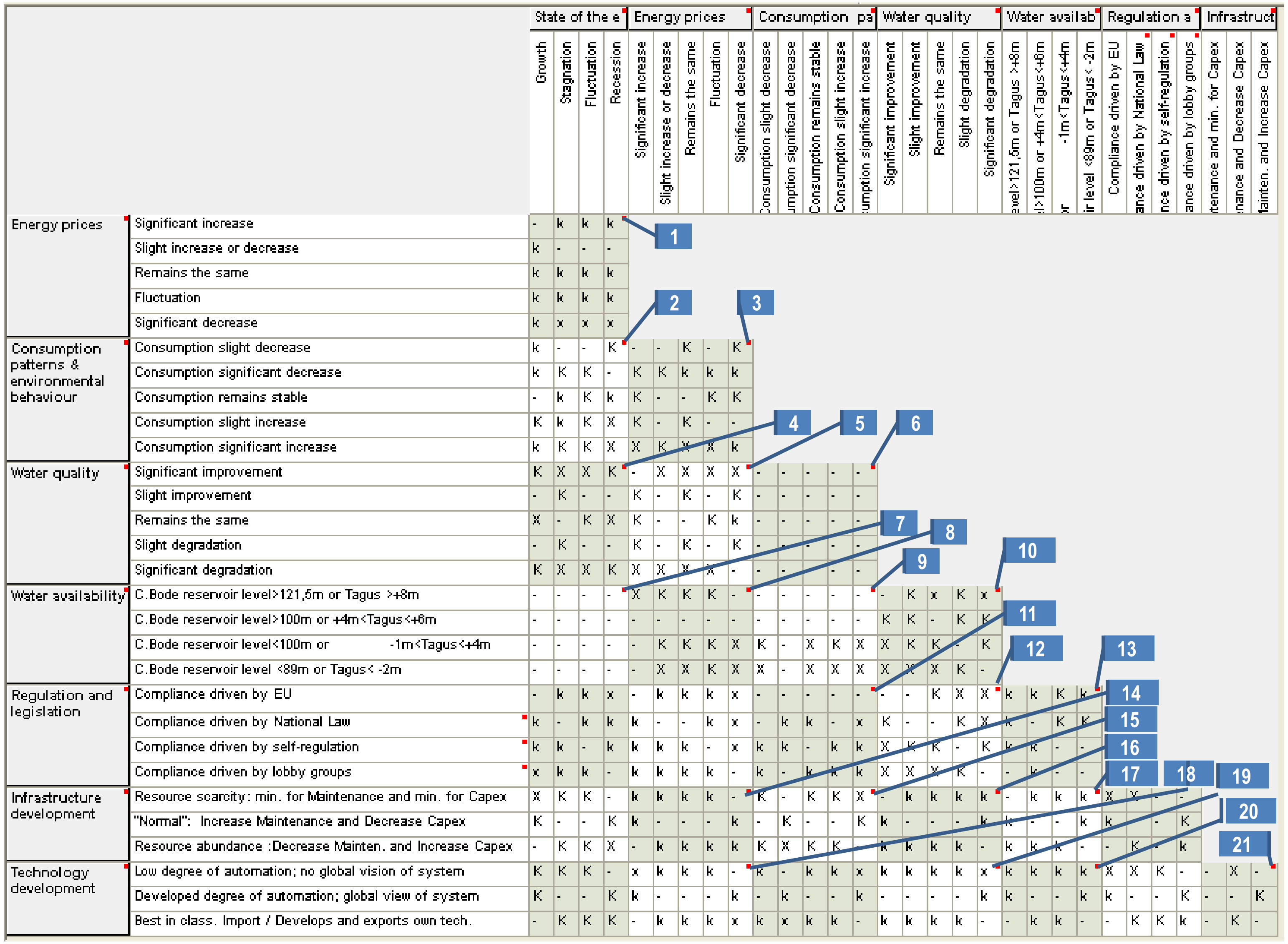
[2] Despite some improvements that can still be made on the suppliers evaluation procedure, the mechanisms to avoid non-compliances with Ethic Code exist (for example, "Public Contracting Code" is now much more restrictive) and there is no track of problems.

[3] It has happened in the past.

[4] More than 200 out of the 740 employees of EPAL are aged 55 years or more.

Appendix H – CCA matrix - assumptions and outputs

		State of the e				Energy prices					Consumption pa					Water quality					Water availab				Regulation a				Infrastruct		
		Growth	Stagnation	Fluctuation	Recession	Significant increase	Slight increase or decrease	Remains the same	Fluctuation	Significant decrease	Consumption slight decrease	umption significant decrease	Consumption remains stable	Consumption slight increase	umption significant increase	Significant improvement	Slight improvement	Remains the same	Slight degradation	Significant degradation	evel>121,5m or Tagus >+8m	l>100m or +4m<Tagus<+6m	or -1m<Tagus<+4m	ir level <89m or Tagus< -2m	Compliance driven by EU	ance driven by National Law	nce driven by self-regulation	ance driven by lobby groups	tenance and min. for Capex	nance and Decrease Capex	ainten. and Increase Capex
Energy prices	Significant increase	-	k	k	k																										
	Slight increase or decrease	k	-	-	-																										
	Remains the same	k	k	k	k																										
	Fluctuation	k	k	k	k																										
	Significant decrease	k	x	x	x																										
Consumption patterns & environmental behaviour	Consumption slight decrease	k	-	-	K	-	-	K	-	K																					
	Consumption significant decrease	k	K	K	-	K	K	k	k	k																					
	Consumption remains stable	-	k	K	k	K	-	-	K	K																					
	Consumption slight increase	K	k	K	X	K	-	K	-	-																					
	Consumption significant increase	k	K	K	X	X	K	X	X	k																					
Water quality	Significant improvement	K	X	X	K	-	X	X	X	X	-	-	-	-	-																
	Slight improvement	-	K	-	-	K	-	K	-	K	-	-	-	-	-																
	Remains the same	X	-	K	X	K	-	-	K	k	-	-	-	-	-																
	Slight degradation	-	K	-	-	K	-	K	-	K	-	-	-	-	-																
	Significant degradation	K	X	X	K	X	X	X	X	-	-	-	-	-	-																
Water availability	C.Bode reservoir level>121,5m or Tagus >+8m	-	-	-	-	X	K	K	K	-	-	-	-	-	-	-	K	x	K	x											
	C.Bode reservoir level>100m or +4m<Tagus<+6m	-	-	-	-	-	-	-	-	-	-	-	-	-	-	K	K	-	K	K											
	C.Bode reservoir level<100m or -1m<Tagus<+4m	-	-	-	-	-	K	K	K	X	K	-	X	K	X	X	K	K	-	K											
	C.Bode reservoir level <89m or Tagus< -2m	-	-	-	-	-	X	X	K	X	X	-	X	X	X	X	X	X	K	-											
Regulation and legislation	Compliance driven by EU	-	k	k	x	-	k	k	k	x	-	-	-	-	-	-	-	K	X	X	k	k	K	k							
	Compliance driven by National Law	k	-	k	k	k	-	-	k	x	-	k	k	-	x	K	-	-	K	X	k	-	K	K							
	Compliance driven by self-regulation	k	k	-	k	k	k	k	-	x	k	k	-	k	k	X	K	K	-	K	k	k	-	-							
	Compliance driven by lobby groups	x	k	k	-	k	k	k	k	-	k	-	k	k	k	X	X	X	K	-	-	k	-	-							
Infrastructure development	Resource scarcity: min. for Maintenance and min. for Capex	X	K	K	-	k	k	k	k	-	K	-	K	K	X	-	k	k	k	k	-	k	k	k	X	X	-	-			
	"Normal": Increase Maintenance and Decrease Capex	K	-	-	K	k	-	-	-	k	-	K	-	-	K	k	-	-	-	k	k	-	-	k	k	-	-	K			
	Resource abundance :Decrease Mainten. and Increase Capex	-	K	K	X	-	k	k	k	k	K	X	K	K	-	k	k	k	k	-	k	k	k	-	-	K	-	k			
Technology development	Low degree of automation; no global vision of system	K	K	K	-	x	k	k	k	-	k	-	k	k	x	k	k	k	k	x	k	k	k	k	X	X	K	-	-	X	-
	Developed degree of automation; global view of system	K	-	-	K	k	-	-	-	k	-	k	-	-	k	-	-	-	-	k	k	-	-	k	k	-	-	K	-	-	K
	Best in class. Import / Develops and exports own tech.	-	K	K	K	-	k	k	k	x	k	x	k	k	-	k	k	k	k	-	-	k	k	-	-	K	K	k	-	K	-



State of the e
Energy prices
Consumption pa
Water quality
Water availab
Regulation a
Infrastruct
Growth
Stagnation
Fluctuation
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Significant increase
Slight increase or decrease
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Consumption slight decrease
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Consumption remains stable
Consumption slight increase
Consumption significant increase
Significant improvement
Slight improvement
Remains the same
Slight degradation
Significant degradation
C.Bode reservoir level>121,5m or Tagus >+8m
C.Bode reservoir level>100m or +4m<Tagus<+6m
C.Bode reservoir level<100m or -1m<Tagus<+4m
C.Bode reservoir level <89m or Tagus< -2m
Compliance driven by EU
Compliance driven by National Law
Compliance driven by self-regulation
Compliance driven by lobby groups
Resource scarcity: min. for Maintenance and min. for Capex
"Normal": Increase Maintenance and Decrease Capex
Resource abundance :Decrease Mainten. and Increase Capex
Energy prices
Consumption patterns & environmental behaviour
Water quality
Water availability
Regulation and legislation
Infrastructure development
Technology development
Low degree of automation; no global vision of system
Developed degree of automation; global view of system
Best in class. Import / Develops and exports own tech.
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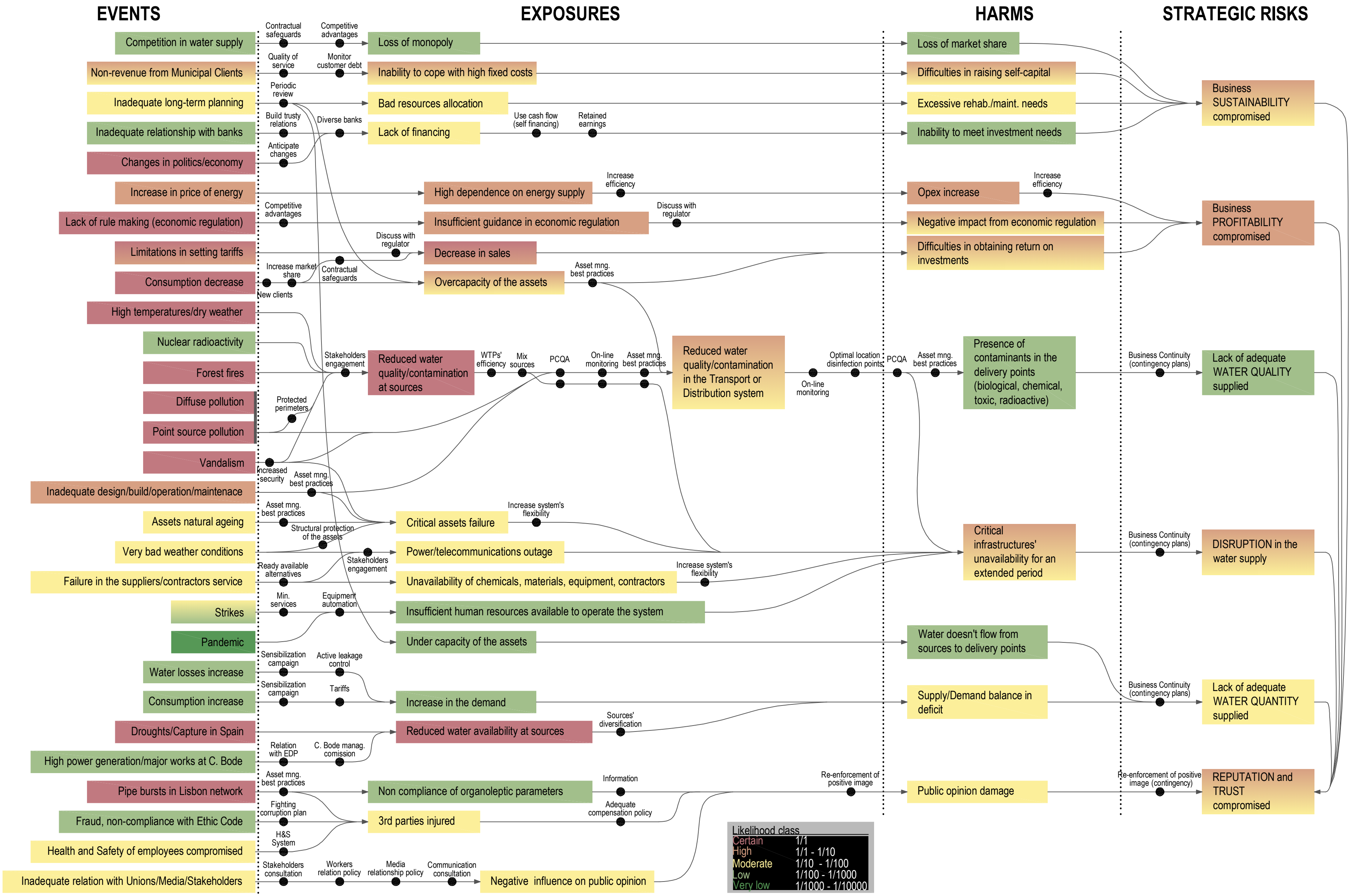
#	Comment
1	Energy prices tend to grow, regardless of the state of the economy. Even with the recession in Europe and USA in recent years, price of energy has not decreased. But, according to “Shell energy scenarios to 2050” (2008), benefits may emerge from accelerated growth in distributed power generation from wind and solar energy; furthermore, OPEC may raise oil production to maintain lower prices and defer the development of more costly substitutes.
2	Consumption patterns are not so related to the state of the economy as they are with climate patterns and behaviours.
3	Increased energy prices may be reflected in water tariffs, leading to a decrease in consumption.
4	State of the economy may influence water quality in two ways: 1) growth = more industrial activity = more effluents / more emissions and increased rate of climate changes' effects; 2) growth = more money to treat effluents, monitor, etc. (environmental sustainable growth).
5	Higher energy prices may lower industry activity, but may also reduce wastewater treatment rates.
6	There is no relation between these 2 parameters.
7	There is no relation between these 2 parameters.
8	If energy prices increase, EDP will use C. Bode reservoir more often.
9	< 100 m will increase the cost of energy in production and hence the tariff; < 89 m will pose limitations to the consumption.
10	This was completed taking into account possible relations between water quality and water quantity, excluding other factors such as anthropogenic causes.
11	Economic regulation via tariffs and leakage reduction incentives
12	It was assumed that EU legislation is the most restrictive
13	Lobbies and self-regulation will lead to a reservoir level higher than 89 (EDP needs water height to produce energy). Albufeira trans boundary agreement allows levels to become lower than -1 m in Valada-Tejo if there is a drought in Spain. Lobby groups may be Spain and EDP (the Portuguese electricity supply company).

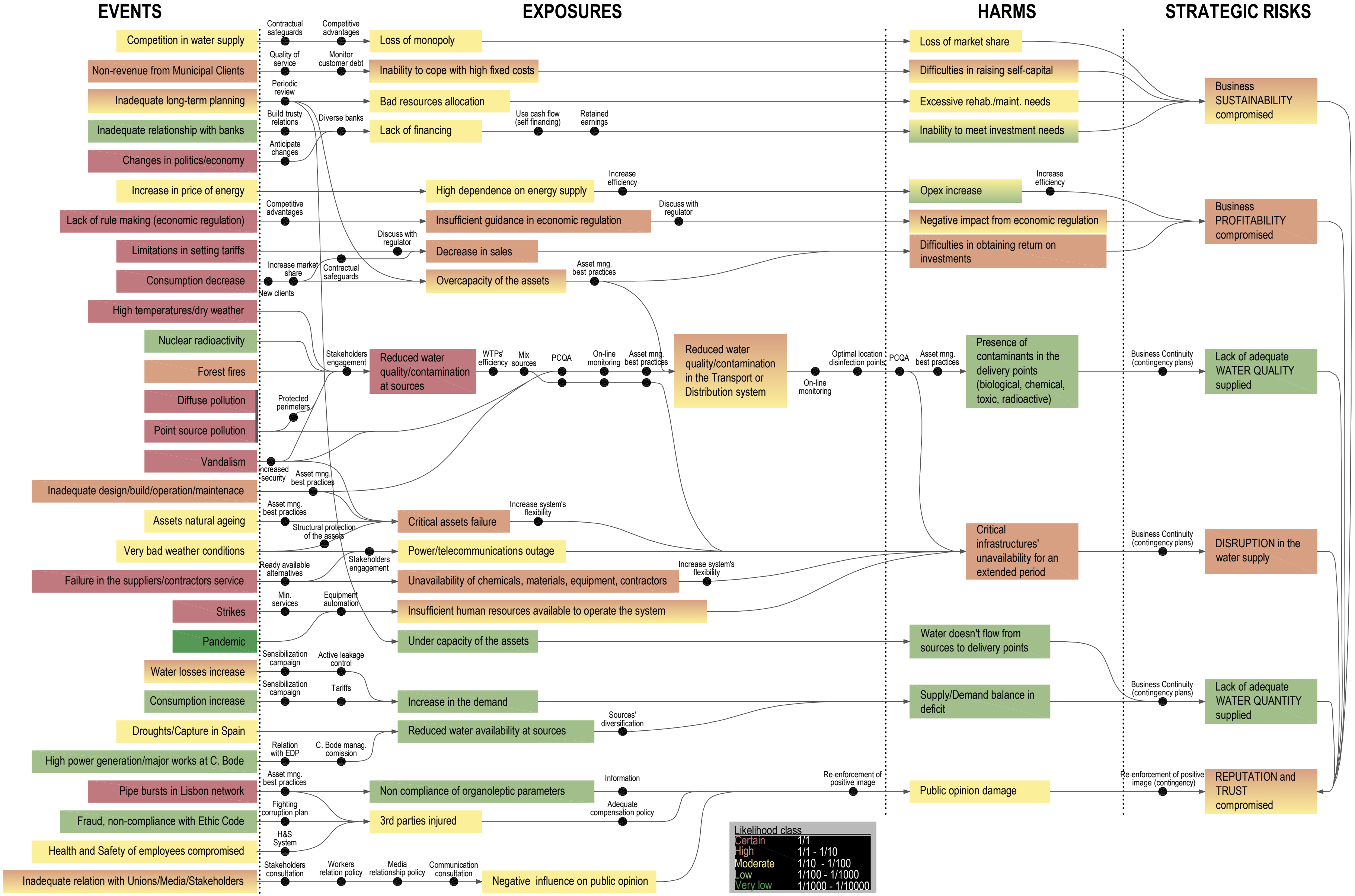
#	Comment
14	Increased energy prices will lead EPAL to invest in more energy-efficient or self-production solutions. But, on the other hand, it may increase Opex (and, thus, reduce cash-flow or increase the tariffs).
15	Higher consumption means there is a higher revenue/cash-flow.
16	Water quality improvement means there is no need to significantly invest in WTP or chlorination points.
17	Water availability means there is no need to invest in further abstractions or solutions to produce water. But, if levels in the reservoir get too high, it will be necessary to invest in assuring the integrity of the infrastructures.
18	The higher the energy price, the best technological solutions are developed in order to reduce energy consumption
19	Degradation of water quality in the sources will lead to the need to install/develop new technology for treatment and monitoring.
20	Too much or too few water will enhance the need to further monitor the system.
21	Even in a context of resource scarcity, it will be possible to become best-in-class in a specific domain. It will be derived from the sense of need to find new (cheaper) solutions.

Appendix I - Baseline risks reassessment under futures scenarios

Scenario 1 - Water Scarcity



Scenario 2 - Financial resources' scarcity



Scenario 3 - Strong economic growth