Health impacts from extreme events water shortages

March 2012

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Executive Summary

Introduction: Water shortages have been documented as a result of flooding and other extreme events in many European countries over recent years. Water shortages maybe associated with a range of human health impacts such as increased risk of dehydration, communicable disease and psychological distress.

The incidence of extreme events has been rising and the impact of climate change is projected to increase the risk for millions of individuals, their homes, their communities, and the infrastructure that supports them. Following extensive flooding and related water shortages in the UK during the summer of 2007, the UK government commissioned Sir Michael Pitt to review the emergency response / recovery and offer recommendations for future event management. This review reported the largest loss of combined electricity, water and sewage services since World War II, with almost half a million people without mains water or electricity.

Aim: This study by Health Protection Agency (HPA) in collaboration with the Drinking Water Inspectorate (DWI) looks at specific health issues. Whilst it is recognised that water companies have plans in place for failures in supply, this document looks at the health effects of extreme weather events that cause longer term shortage[1] requiring a sustained response over a longer period of time. A search of the scientific literature and evidence base on loss of water supply in flooding and other extreme events was combined with the findings generated from an interactive workshop of UK water company and health care professionals held on 8th July 2011. This completed report elaborates on aspects of the existing document "Drinking Water Safety – A guide for Water and Health Professionals" which was published in 2009 (DWI/HPA 2009).

Methods: A literature review was undertaken to gather evidence, studies and information from a wide range of peer reviewed and grey literature. Published journals were consulted in conjunction with official water company reports, national and international guidance. A workshop was facilitated in order to gain feedback from water company and health professionals on this document and offer them the opportunity to incorporate their own experiences and knowledge.

[1] In this document a prolonged incident is defined as 5 days after a Major Incident is declared. (SEMD guidance 6 (DEFRA 2009)

Results: The findings reconfirm the importance of water companies and health care professionals achieving a common understanding of the roles and responsibilities in delivering a synchronised response, and a coordinated communication strategy that is diverse in its delivery yet consistent in content. The absence of robust evidence based scientific studies on water shortages in extreme events was demonstrated. Despite the number of published reports and reflective reviews following extreme events, these do not contain rigorous scientific evidence on the health outcomes of these same episodes. This demonstrates the need for health professionals to focus on their role of health surveillance during and following events in order to develop the empirical data base to underpin policies and practice.

Points for Consideration: Government policy is for emergency plans to go beyond the routine operational events and prepare for events which may cut off water to a large number of consumers for over 72 hours and may involve more than one water supply or company (DEFRA/Welsh Assembly Government 2007) It also needs to be taken into account how the extreme event will affect logistics of distribution of alternate supplies, the health of the population without a water, supply, power sanitation and how these periods will differ from routine operational events. Extreme events affect health beyond drinking water and this is to be taken into account when planning the response and recovery.

It is also important that water companies and health professionals have a common understanding of the needs of vulnerable populations, who will require help and why certain groups of people may be more susceptible to potential adverse health effects as a result of water shortages with wider sanitation issues

During the first workshop it was suggested that this document be updated and revised following extreme events when enhanced surveillance is undertaken. The aim of this will be to identify and incorporate published evidence, scientific literature and the lessons identified from events that will take place after publication of this initial document. It was noted that DWI holds regular seminars with water companies each year and one of these should focus on health surveillance and learning.

Finally, it has been shown that the research in this area needs to be built and expanded on. Although the SIGN guidance categorises most of the literature as a level D, it is recognised by the research team the value that reports by the DWI and other DWQ regulators in the UK bring. Due to the nature of disasters, their inherent unpredictability and the immediacy required of the response it is often not possible to undertake rigorously pre-planned

randomised control trials. However, pre-planned enhanced health surveillance protocols can and should be developed and applied to improve the knowledge base. Expanding the scientific literature and making the opportunity to conduct research in this field is essential for the future knowledge base and developing our resilience.

Points for Consideration

The following tables summarise the points for consideration that have been obtained through the literature review, workshop and expert consultation. They have been split into four main categories.

1. Points for consideration with established and documented processes, protocols, roles and responsibilities
2. Points for consideration which may not currently be adopted across all stakeholders
3. Points considered where further work is recommended.
4. Research and future development needs – A summary of the research needs that were identified during the literature review process that would strengthen the evidence base on which guidance is made

Points for consideration with established and documented processes, protocols, roles and responsibilities

AREA	Status and Owner Organisation	Grading by SIGN Guidance
Emergency planning that includes		
• The planning for severe supply interruptions that exceed the duration and scale of routine operational events	In place with Water Companies and DEFRA (SEMD) (DEFRA 2008)	D
• A clear description of the roles of each organisation, agency, individual, voluntary group or team that will respond	In place with Water Companies and DEFRA (planning for Major Water and Waste water Incidents in England and Wales Generic guidance 2006)	D
• Identification of alternative sources of water and any early changes in their quantity and quality (Aergeerts, 2010)	Water Companies through Regulation 27 risk assessments. The Water Supply (Water Quality) Regulations 2000 as amended.	D
• Responses that are able to be activated remotely and should not depend on the emergency team having to access buildings or roads that may be cut off by flooding/snow or windstorm damage.	DEFRA, DWI and Water Company contingency plans	D
• An understanding of how extreme events can impact on services, showing the management and mitigation of these risks.(Ofwat, 2007)	Water Companies through Regulation 27 risk assessments. The Water Supply (Water Quality) Regulations 2000 as amended	D

AREA	Status and Owner Organisation	Grading by SIGN Guidance
Emergency planning that includes (cont…)		
• Involvement of the community and supermarkets in formulation of plans and engagement with Local Resilience Forums	Local Resilience Forum Water Industry and Local Resilience Forums (LRFs)- see http://www.cabinetoffice.gov.uk/sites/default/files/resources/vulnerable_guidance.pdf	D
• **Quantity**		
• A statement about the minimum quantity of water required per person after an extreme event. Currently, the sphere standards state the minimum quantity of water to provide should be 15 – 20 litres / person / day to allow for drinking and essential hygiene activities (Sphere 2011). In the UK it is 10 litres and after five days, 20 litres is strongly recommended (Ofwat, 2007; Water UK, 2008)	SEMD guidelines – guidance 6.	C
Quality		
• Advice to the public that water from tankers is advised to be boiled to avoid secondary contamination. Duty of water companies to oversee supplies.	Duty of water companies to oversee supplies. Code of practice (BS8551) is due to be published. Provision and management of temporary water supplies and distribution networks (not including provisions for statutory emergencies).	D
Communication		
• Pro-actively inform stakeholders on the importance of protecting water pipes during cold weather and their own responsibility	Through water industry websites and other communication	D

Points for consideration which may not currently be adopted across all stakeholders

AREA	Status and owner organisation	Grading by SIGN Guidance
Emergency planning that includes		
• Training and practice exercises in water delivery in extreme events to include the use of large sized vehicles and identification of which roads could be suitable to travel on.	Government, DEFRA and Water industry exercises	**D**
• Allowing communities to view plans to strengthen relationships and build trust.		
• Identifying all possible vulnerable groups at risk from water shortage	Water Company will liaise with Local Authorities	
• Consideration for the indirect public health effects of using many tankers on roads and the carrying of heavy containers		D
• The description of activities and actions required in the event that critical sites and / or infrastructure become unavailable due to an extreme event (Aergeerts, 2010)		D
Alternative Supplies		
• The possibility of military involvement to support mobilisation and assist secure distribution of supplies, although with due consideration to the criteria for their deployment.	Military Aid to the Civil Community (MACC) or Military Aid to the Civil Power (MACP) requested by SCG.	**D**
• The supervision of tankers, where feasible, to avoid vandalism, aid filling and allow dispersal of important health advice and information in person. Category 1 responders could assist if operational needs arise.		**D**

AREA	Status and owner organisation	Grading by SIGN Guidance
Communication		
• Advice that is easy to access and understand, incorporating a range of languages. It should be pre-prepared and ready to be disseminated immediately	Water Companies have established plans for use of notices.	D
• A statement that the aim of communication about health impacts should be diversity in delivery but consistency in content.		D
• One designated agency leading on advice delivery where possible. . Volume of advice being delivered should be controlled to avoid overloading the public with too many messages at once.	Water Companies Lead on communications about the water supply. This will feed in any external response structure eg LGD, Gold	D
• Advice incorporating the health related reasons *why* consumers are being asked to perform techniques such as boiling and also information on avoidance of burns and carbon monoxide poisoning. Generic FAQs should be developed in partnership		D
Vulnerable Groups		
• Extensive use of the third sector to help the authorities in the distribution of water, particularly for those who are unable to leave their houses or carry heavy loads.	Local authorities co-ordinate the activities of the various sector agencies and spontaneous volunteers.	D
• In a protracted event, communication regarding possible unsuitable alternative water sources and potentially unsafe methods of boiling water.	Bouchier Report DWI website	D

Points considered where further work is recommended

AREA	Status and owner organisation	Grading by SIGN Guidance
Vulnerable Groups		
• During and following an extreme event there must be monitoring of those classed as vulnerable to ensure that they are gaining access to sufficient safe clean water, particularly the elderly.	Recommendation for further consideration – HPA to lead in conjunction with other Health Professionals	D
• Review of literature to ascertain evidence base to assure communication on advice for infants requiring bottle feeding are receiving bottled water with the correct sodium content.	HPA and partner organisations researching to provide evidence base.	D

Research and areas for future development

Quantity
• The quantity of water required by populations after an extreme weather event requires future research. Reflections from case studies have shown that this may need to be revised.
Vulnerable Groups
• The requirements during water shortages by vulnerable populations need to be further researched.
Documenting & Publishing Events
• Grading of evidence needs to take account of the fact that during extreme events, it is not possible to conduct studies at the higher end of the research hierarchy. Case studies, grey literature and reflective reports from actual events are an extremely valuable method of identifying lessons for future events.
Health related studies
• Explore the need for an agreement between Health Protection Agency and Primary Care Trusts/Clinical Commissioning Groups to undertake appropriate enhanced surveillance of the health of the affected population during and after an extreme weather event, to include the development of “how to” protocols relating to enhanced surveillance, health and water shortages • Professional development of health sector staff in water related information should form part of their routine training • Enhanced surveillance undertaken in extreme weather events to be formally documented and written up for publication where applicable

Conclusion: Given the recent projections on climate change and the future impacts it will have on extreme events, it is clear that European preparedness, response and recovery within public health and water shortages is essential. Recent reports of water shortages as a result of extreme events affect significant numbers of people and have highlighted the need to build robust, coordinated plans which are based on scientific evidence.

Overall Conclusions

1 Health impacts change over time during large events. Loss of water supply in conjunction with loss of power over time may create sanitation problems, so these events cannot be viewed as only in terms of water quality.

2 These impacts can be predicted in advance and planned for, in relation to alternate supply provision, advice to consumers and health surveillance.

Acronyms

CDC	Centre for Disease Control and Prevention (USA)
CI	Confidence Interval
CO	Cabinet Office
DEFRA	Department of Environment, Food and Rural Affairs (UK)
DWI	Drinking Water Inspectorate
EA	Environment Agency (UK)
EE	Extreme events
EEHPS	Extreme Events and Health Protection Section
EPA	Environment Protection Agency (USA)
FSA	Food Standards Agency (UK)
GCC	Global Climate Change
HPA	Health Protection Agency (UK)
IPCC	Intergovernmental Panel on Climate Change
IRR	Incidence Risk Ratio
LRF	Local Resilience Forum
MACC	Military Aid to Civil Community
MACP	Military Aid to Civil Power
MeSH	Medical Subject Heading (database terminology)
NGO	Non Government Organisation
NI	Northern Ireland
SCG	Strategic Co-ordination Group
SIGN	Scottish Intercollegiate Guidelines Network
SEMD	Security and Emergency Measures Direction
UK	United Kingdom
USA	United States of America
WHO	World Health Organization
WMO	World Meteorolgical Organization
WTW	Water treatment works

1. Introduction

1.1. Background to document

1.1.1 In the summer of 2007 England and Wales had extensive flooding leading to water shortages. The Pitt Report, published in 2008, was a comprehensive review of the lessons identified from these floods (Pitt, 2008). It states that in the summer of 2007, 55,000 properties were flooded; around 7,000 people were rescued from the flood waters by the emergency services and 13 people died (Pitt, 2008). In addition it was reported that the floods resulted in the largest loss of essential services since World War II, with almost half a million people without mains water or electricity. Further transport networks failed, and emergency facilities were put out of action.

1.1.2 The review put the events into context by reporting that there were over 200 major floods worldwide during 2007, affecting 180 million people with the human cost of more than 8,000 deaths and over £40 billion worth of damage (Pitt, 2008). However, even against that dramatic back-drop, the floods that devastated England ranked as the most expensive in the world in 2007 (Pitt, 2008).

1.1.3 Specifically under the response frameworks of the Pitt Review (Pitt, 2008), the following was stated:

> **"ES.71** The loss of Mythe water treatment works left some 350,000 people without mains water for more than two weeks. This created the major challenge of providing large volumes of drinking water. Severn Trent Water's contingency plans were unable to meet the scale of the supply required. An extensive and effective logistical operation for the sourcing and distribution of bottled water was set up to meet the needs of the public. Special arrangements, involving the Armed Forces, had to be established.
>
> **"ES.72** In accordance with existing regulation, at least 10 litres of water were supplied to each affected person. However, while 10 litres of water may have been acceptable in meeting the immediate and essential needs in the initial stages of the emergency, it was insufficient to meet the longer term needs of the public. There were particular problems for vulnerable groups such as the chronically sick and those with young children."

From this the following recommendation was made:

"RECOMMENDATION 40: DEFRA should amend emergency regulations to increase the minimum amount of water to be provided in an emergency, in order to reflect reasonable needs during a longer-term loss of mains supply" (Pitt, 2008).

1.1.4 As a result, this document has a focus on flooding as this is considered to be the extreme event whose risk will increase the most in England and Wales (latest research shows between a 200-5000% increased risk in some areas (Oven *et al*., 2011). However, at the request of the DWI, the Extreme Events and Health Protection Section (EEHPS) of the Health Protection Agency (HPA) considered water shortages in the context of other natural hazards. The need for drinking water is key, but attention needs to also be given for the supply of water for washing, food preparation and sanitation purposes.

1.1.5 The HPA and DWI have already produced guidance on alternative supplies during short duration water shortage and contamination of supplies (DWI/HPA, 2009). However, this report will address the guidance on water shortages as a consequence of extreme large scale events leading to longer duration interruptions in supply, as noted by recommendation of the Pitt review.

1.1.6. This document includes a summary on the impacts of health from water shortages, a review of case studies on previous water shortage events, discussion on lessons identified from past responses and development of a table highlighting essential points for consideration for future events.

1.1.7 It is intended for use by the DWI to advise government ministers and water companies on the public health effects of water shortage during and following extreme events. The wider audience is intended to include, but is not limited to, water companies requiring public health information and health professionals who work with water companies during the emergency response. It is intended to serve as the necessary information to support the actions which are already advised and planned by water companies within their emergency plans.

1.2 Outline of the document

The following processes were used in the formulation of the points for consideration:

1.2.1 First, a literature review was undertaken of the evidence base (current research) for water shortages during extreme events. This included peer reviewed studies, grey literature such as national and international organisational guidance, water company documents, reflective reports and case studies.

1.2.2 A workshop was then conducted which was attended by experts and practitioners appropriate to this field, in order to discuss the issues and recommendations in the first order draft document

1.2.3 Both the literature search and the workshop summary were then used to develop appropriate evidence-based information for the provision of water during extreme events.

1.3 Extreme events

1.3.1 Extreme events are often referred to as extreme weather events, natural hazards, natural disasters, severe weather or severe weather events and are known to pose a risk of water shortage as a result of their impact on water resources and infrastructure (Aergeerts, 2010). For the purposes of consistency, they shall be referred to as extreme events throughout this document.

1.3.2 Extreme events are predicted to increase in frequency and intensity as a consequence of global climate change, thus increasing the risk to millions of homeowners and industries (Sinisi, 2010; IPCC, 2007). The Intergovernmental Panel on Climate Change (IPCC) forecast that extreme event episodes will increase due to intensified precipitation, global temperature rises, rainfall fluctuations, escalating periods of droughts, sea level rise and increased periods of extreme heat (Sinisi, 2010; IPCC, 2007). Changes on a global scale pose new challenges for the health sector and water industries as current safeguards will require assessing and new technologies capable of protecting against and adapting to climate change will need to be developed as a priority (Foster, 2010).

1.3.3 The demand for drinking water supplies will become more acute as the global population increases, year-round temperatures rise, consumer and agriculture consumption grows and extreme events affect sources of supply. Extreme events as a result of global climate change may impact sources of supply and increase pressure on water companies through:

- Decreased precipitation leading to reduced volumes of stored water in reservoirs served by seasonal rivers
- Increased pressure on groundwater
- Temperature fluctuations impacting on
    - the water supply network and
    - increasing the risk of potential operational and water treatment process problems
- A cycle of intense precipitation, flooding, drought and heatwaves creating increased soil movement and heightening the risk of water supply pipes cracking (Foster, 2010).

1.3.4 The traditional focus of the health sector has been on the response to emergencies. The ongoing challenge is to broaden the focus of disaster risk management for health from that of response and recovery to a more proactive approach which emphasises prevention, mitigation and the development of community and country capacities to provide timely and effective response and recovery (WHO/HPA, 2011; UNISDR, 2009). Resilient health systems based on primary health care at community level can reduce underlying vulnerability, protect health facilities and services, and scale-up the response to meet the wide-ranging health needs in disasters. All these effective health care services require access to water even in water shortages as a result of extreme events.

1.3.5 In a recent questionnaire study of the WHO Regional Office for Europe's 53 countries, water shortages were highlighted as a consequence of flooding by a number of respondents (WHO/HPA, 2011).

1.3.6 Water shortages initiate a dedicated and pre-planned emergency response from water companies regardless of the reason for the shortage. However, when an extreme event is the reason for the shortage there will be other specific factors which will need to be taken into account. These include blocked access routes due to flooding or snow which will lead to difficulty in the delivery of supplies and mobilising of key response staff. Depending on the nature of the event, extremes of temperature may impede technical or human resource related operations and due to the scale, staff may have been affected themselves.

1.4 Disaster management cycle

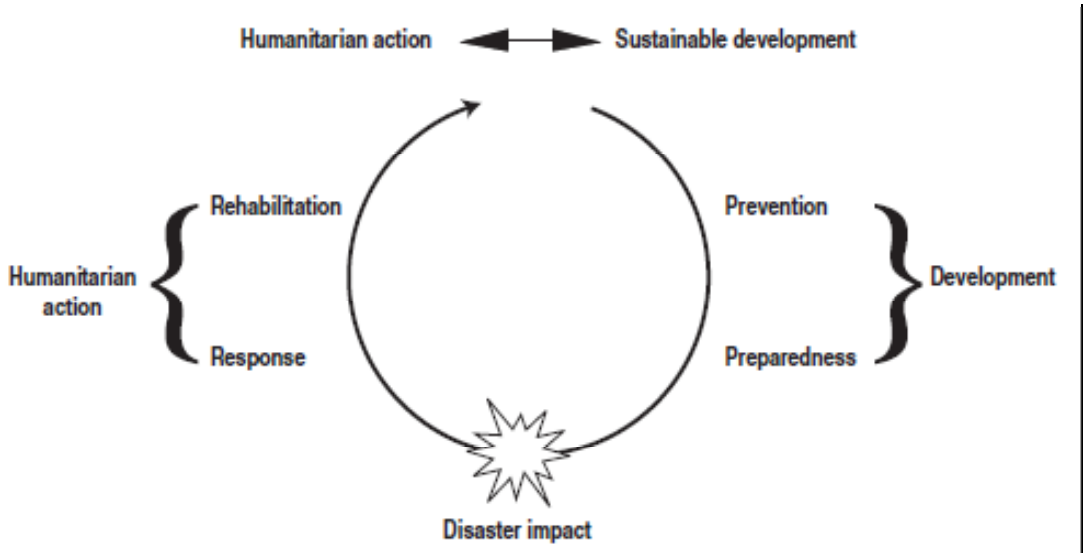
1.4.1 Extreme events and other emergencies often result in significant impacts on people's health, including the loss of many lives. Every new threat reveals the challenges for managing health risks and effects of emergencies and disasters. Deaths, injuries, diseases, disabilities, psychosocial problems and other health impacts can be avoided or reduced by disaster risk management measures involving health and other sectors (WHO/ HPA, 2011).

Disaster risk management for health is multisectoral and refers to the systematic analysis and management of health risks, posed by emergencies and disasters, through a combination of:

- hazard and vulnerability reduction to prevent and mitigate risks,
- preparedness,
- response
- recovery measures

Figure 1 summarises this four stage process considering where humanitarian action and sustainable development sit and how they work together within the disaster management cycle (Wisner and Adams, 2003)

Figure 1 the disaster management cycle



(Wisner and Adams, 2003)

2 Methods

2.1 Literature review

The literature review aimed to retrieve papers on the public health impact of water shortage and the lessons identified from previous emergencies. Peer reviewed and grey literature was collected in the systematic fashion described in appendices A, B and C. Databases searched included Medline, Global Health, Embase and the Cochrane Collaboration with limits set to “English” “2005 – current” and “human”. Retrospective, prospective and hand based journal searches were also undertaken alongside contact with relevant professionals in this field to identify articles and papers.

Papers covering water shortages as a result of extreme events within European or developed countries were included. Research from the African and Asian continents was excluded due to the complex differences in population, climate and infrastructure making extrapolation to our UK setting difficult.

2.2 SIGN guidance and evidence grading

It is generally accepted that guidelines for aspects of both medical and public health should always be based on available research evidence. However, in order to adequately demonstrate that the evidence available has been assessed for quality and that the recommendations are being put forward are based on that quality assessment, a system is required. This is why the SIGN Guidance was developed (SIGN, 2011). There are other methods available such as NICE (2009) and the Centre for Evidence-Based Medicine (2009). SIGN was chosen for the development of this document because it is held in high regard as a method for this process and it allows for the fact that the evidence may not be at the top level of the research hierarchy. Full details on SIGN guidance methods can be found in appendix D.

2.3 Case studies

Retrieved peer reviewed studies, grey literature, official reports and reflective documents were used to highlight pertinent case studies. These case studies were used as relevant examples of when water shortages have occurred as a result of extreme events. The responses and lessons identified were extracted and considered alongside the scientific evidence base. Examples of how the response was managed and reflected will aid in the formulation of the points for consideration for future preparedness and response.

2.4 Workshop

A workshop was held on Friday 8th July 2011 to generate discussion around the topic, reflect on the first draft of this document and record the opinions and views of a number of experts in the field of water and health. Their experiences and feedback has aided the development of this final document.

3 Results

3.1 Literature review

3.1.1. Appendix E summarises the database search results. The majority of papers on the topic of water shortage, flooding and public health responses were excluded since they were conducted in incomparable settings or related to water contamination unrelated to extreme events or emergencies. Following the addition of the papers retrieved from prospective, retrospective and author searches, the total was 24.

3.1.2 The small number of peer reviewed articles found by the project group on this subject has been reflected in previous reviews. Ahern *et al.* (2005) highlight the need for research in this field stating that not only are the public health consequences of importance but also the evaluations of any interventions intended to reduce health risks (Ahern *et al.,* 2005). They suggest the lack of studies is a possible result of the unpredictable and sudden nature of flooding alongside the lack of baseline data available on sample populations (Ahern *et al.,* 2005).

3.1.3 This project therefore relies heavily on grey literature. This includes reflective reports, policy documents, case studies, guidelines from various agencies and lessons learnt from previous floods. Although not peer reviewed, valuable reports were found such as that commissioned by Severn Trent Water after Gloucestershire's flooding. They undertook focus group discussions and analysis of consumer complaints and formulated detailed lessons learned and recommendations (Severn Trent Water, 2007).

3.1.4 The literature review generated five main themes of importance in the public health response to water shortages during or immediately after floods, namely health impacts, water quantity, alternative supplies, communication and emergency response. The results are discussed in sections 6 to 10.

3.2 Evidence assessment summary

Number of	Number	Number	Number	Number	Number

Articles Reviewed	Graded 1- or above	Graded 2-, 2 or 2+	Graded 3	Graded 4	not applicable
84	**0**	**10**	**45**	**24**	**5**

3.3 Case studies table

Case studies of water shortages during or following extreme events were extracted from the available literature and have been summarised in Table 1. They have been presented together according to the event to include flooding (UK, Hungary) cold weather (Northern Ireland, Hungary), drought (Azerbaijan) and algal blooms (Italy in 2009). All extreme events which led to a disruption in mains water supplies have been included.

FLOODING

COUNTRY / YEAR	EVENT	DESCRIPTION OF EVENT	IMMEDIATE RESPONSE
ENGLAND 2007 Water UK (2008) OFWAT (2007) Severn Trent Water (2007) Foster (2010)	FLOOD 6 WTW Seriously affected	Flooding of Mythe water treatment works and subsequent closure. Mythe was the single source for large population Unprecedented scale – overwhelmed emergency plan Mythe - 350,000 cut off from water supply for up to 16 days Fulstow – 2500 cut off for 2 hrs Ewden – closed for 7 weeks – nobody affected. Grimsbury – Closed for more than 2 months – nobody affected Whitbourne – closed for 2 days. 3,800 properties without water for 1 day. Significant disruption to transport, electricity supplies and provision of water and sanitation services. No direct health effects reported	Transferred a number of properties to alternative supply system. 1500 bowsers (1950 available but vandalism problems prevented use) in 1100 locations Refill bowsers 3 times / day through systematic “milkrounds” 20 litres/person/day 3 million litres bottled water distributed / day in 24 distribution points Employed ‘mutual aid scheme’ borrowing equipment and staff from other water companies 1800 employees 24 / 7

HUNGARY Foster (2010) Dura *et al.* (2010)	FLOOD Karst water springs inundated	Large amount of rainfall causing strong water flow and flooding. Microbiological contamination from a number of sources into wells and water mains 3673 people became ill, 161 admitted to hospital (population 60, 000)	Safe drinking water supplied Identification of contamination Risk reduction and prevention actions
ENGLAND & WALES 2000	FLOOD	Catchments waterlogged. Extensive Power cuts & pollution of groundwater. Sewer flooding	Boil water notices
CZECH REPUBLIC 1997	FLOOD	7,300 cases registered Leptospirosis. 13 of the 14 outbreaks were due to undisinfected groundwater post flood.	Boil water notices
IRELAND 2009 Gavin (2009)	FLOOD	18, 000 households cut off from mains water following flooding of waterworks.	Appropriate major incident plans initiated. Council sent out tankers with alternative supply. Vulnerable groups identified and extra human resources obtained. Rotation of supplies via alternative pipes maintained supply. 300,000 litres of bottled water distributed. Army assistance given

COLD WEATHER			
COUNTRY / YEAR	**EVENT**	**DESCRIPTION OF EVENT**	**IMMEDIATE RESPONSE**
NORTHERN IRELAND **2010/2011** Utility Regulators (2011) Northern Ireland Environment Agency (2011)	**FREEZE-THAW** 450,000 consumers – interrupted supply	Temperatures coldest for 100 yrs The cause of the water supply failure was the extreme weather - sub-zero temperatures for eight days. pipes freeze then burst when the thaw came. three-fold increase in burst water mains Around 80% of the additional water demand caused by the freeze thaw leaked from domestic and business water pipes. The remainder was lost from NI Water's network. Problems identified and notified to the drinking water inspectorate at some WTWs included; instrument faults; response to alarms; freeze/thaw damage, effects of low temperature on the coagulation process and increased production. No identified problem with infrastructure of pipes. Assets performed well.	Increased volume in pipes to account for losses due to leaks in burst pipes. Rotation of supplies led to service interruption for 380,000 consumers over the whole rotation period. Water production at the WTW reached near capacity. 160 bowsers deployed 100,000 bottles in stock – additional aid was required to provide supplies and distribute. 10 Standpipes provided
HUNGARY 2009 *Compiled by representatives of the National Institute of Environmental Health, Hungary* cited in Foster (2010)	**SNOW**	In Western Hungary a large amount of snow fell as a result of a cyclone Snow fall on power cables caused damaged due to excess weight. Power cut affected 34 settlements and 89,000 consumers Power supply interrupted to pumps and equipment of both water utilities. Shortage of backup generators Pressure in water supplies fell and varied significantly Concern of ground and waste water feeding back into water pipes	Boil water notice due to reduced pressure in pipes Water tankers to ensure sufficient supply

DROUGHT / WATER SCARCITY			
AZERBAIJAN **Ongoing** Foster (2010)	**WATER SCARCITY**	Vulnerability assessments suggest 15 – 20% decrease in available water resources.	Building of new reservoirs and increasing efficiency of existing ones Irrigation systems and afforestation Improvement of water management systems Reducing demand through water saving technologies Reconstruction of existing systems
WINDSTORM			
USA **2005** CDC (2005) Ram *et al.* (2005)	**HURRICANE**	Hurricane Katrina caused widespread damage to New Orleans Infrastructure and essential services such as electricity and water supplies was affected. A significant number of people were left without water or power	Alternative supplies had to be mobilised.
ALGAL BLOOOM			
ITALY **2009** *Compiled by Funari E Higher Institute of Public Health, Italy.* Cited in- Sinisi and Aergeerts (2010)	**ALGAL BLOOM**	Bloom of cyanobacterium “Planktothrix rubescens” in a 13km wide artificial reservoir of over 270 million cubic meters of water. Served 800,000 comsumers Algal density exceeded 150 million cells/litre	Mitigation of risk of toxin presence in drinking water Communicating risk information to target population and authorities

4 Extreme events and water shortages

4.1 Whilst it is acknowledged that water companies have well developed, tried and tested plans for delivery of water during water shortages, the nature of extreme events often brings extra challenges. Accessibility to the communities and individuals who require the emergency supplies is often compromised, the working environment can be made extremely challenging and consumers may be at increased risk of dehydration due to the nature of the event.

4.2 Although individual extreme events can all increase the risk of drinking water contamination for different reasons, this document will focus on their specific relationship to water shortages. For further information and guidance on water contamination, the reader is advised to consult the “Guidance on water safety for water and health professionals” document (DWI / HPA, 2009).

5 Extreme event definitions

5.1 Appendix F details different types of extreme events and provides their basic definitions, outline of early alerting and the relationship between the event and drinking water shortages. Case studies, grey literature, official reports of known incidents and contact with the Drinking Water Inspectorate (DWI) have formed the base of why extreme events can lead to a shortage of drinking water.

5.2 Definitions have been given in order to promote a common understanding on the subject. However, these may vary between fields and often have colloquial applications. Although the UK is fortunate not to experience all the extreme events described, an explanation of all the major extreme events has been given as they have caused disruption of water supplies in other countries. These events such as hurricanes in the USA and tsunamis in Japan are important in order to enhance our learning for the future as they have provided the transferable lessons identified from previous events.

5.3 Appendix G contains a table showing the possible impacts of extreme events as a result of climate change and their consequences for water resources.

6 Health

6.1 The Health impacts of water shortage

6.1.1. Water supplies may be disrupted for relatively short periods of time (hours), or may persist for substantially longer periods (days to weeks) depending on the severity of the extreme event and the damage caused to the water supply system.

6.1.2. The literature has significantly less coverage of the health implications of water shortage or lack of provision after extreme events. The physical effects of a lack of water on the body are outlined below, but some assumptions have to be made about the wider implications of short, medium and long term water shortage.

6.1.3. Water intended for human consumption is defined by the European Community's Drinking Water Regulations as ***"all water, either in its original state or after treatment, intended for drinking, cooking, food preparation or other domestic type purposes, regardless of its origin and whether it is supplied from a distribution network, from a private source or by tanker or similar means"*** *(p6)* (European Parliament, 2007).

6.1.4. Access to safe water is essential for survival, a basic human right and vital for effective health protection (Smith *et al.,* 2006; Sphere 2011). As Jequier and Constant (2010) explain in their review on the physiological basis of hydration, ***"[water] acts as a building material: as a solvent: reaction medium and reactant: as a carrier for nutrients and waste products: in thermoregulation / and as a lubricant and shock absorber"*** *(p115) (*Jequier *et al.,* 2010).

6.1.5. Water also allows essential activities of daily living at the domestic level as well as the vital functioning and provision of patient care in hospitals and health facilities (Smith *et al.,* 2006; WHO, 2005).

6.1.6 The health implications here should also be seen in the light of other health problems associated extreme weather events as a whole. These can include respiratory problems, coughs, colds, upset stomachs, throat and ear infections, headaches, shock, skin irritations, hypothermia, high blood pressure, cuts, bruises and other physical injuries (Carroll *et al.,* 2010). Physical injuries generally happen when people try to move themselves, family or belongings from danger (Ahern *et al* 2005). There are also short and long term psychological effects such as anxiety, depression

and stress among those directly affected (Tapsell and Tunstall, 2008; Carroll *et al.,* 2010).

6.1.7 In the 2008 International Symposium on Cyanobacterial Harmful Algal Blooms, Hilborn *et al.* (2008) reported that acute exposures to cyanobacteria and their toxins may occur via the oral, dermal, inhalational or intravenous exposure routes. They also note that acute human exposure has been documented via contamination of dialysate in hemodialysis clinics (Pouria *et al.,* 1998) and that outcomes may range from no apparent effect to serious morbidity or death. Toxicosis to non life–threatening allergic and allergic–like reactions (rhinitis, asthma, eczema, conjunctivitis) have also been reported but are poorly quantified as are acute illnesses (e.g. flu–like reactions, skin rashes) in (presumably) non– allergic individuals.

6.2 Dehydration

6.2.1 The elderly, children, infants and those with pre-existing illnesses are particularly at risk from dehydration (Bennett, 2000). Symptoms of mild dehydration include (amongst others), tiredness, dry mouth, thirst, decreased urine output, headaches and increased risk of urinary tract infections in the elderly (Bennet, 2000). Severe dehydration can present with extreme thirst, confusion, little or no urine output, low blood pressure, rapid heartbeat, delirium or unconsciousness (Bennet, 2000).

6.2.2 Dehydration can rapidly occur in periods of extreme heat as a result of excessive sweating and inadequate oral intake of water. Coronary and cerebral thromboses (blood clots in the heart and brain vessels) are thought to be a result of haemoconcentration and a thrombogenic increase in viscosity and the density of platelets and red blood cells (WHO, 2004). It is essential that in extreme events such as heatwaves, people are provided with adequate volumes of water to drink as dehydration alone can produce hyperthermia (dangerously high body temperature) (Allen, 2009).

6.3 Infectious disease

6.3.1 Due to a lack of clean water and sanitation, there can also be an increased risk of faecal-oral disease transmission (WHO, 2010a; Ahern *et al.,* 2005; Dura *et al.,* 2010). WHO state that “ensuring an uninterrupted provision of safe drinking water is the most important preventive measure to be implemented following flooding, in order to reduce the risk of outbreaks of water-borne diseases” (WHO, 2005). Acute

gastrointestinal illness was found to be associated with loss of water provision or pressure after freezing temperatures in Alabama (CDC, 2011). Extreme heat can also lead to increased infectious disease as there is less dilution of contaminants in sewage and other water dependant systems (Menne, 2010).

6.3.2 Although large outbreaks following European floods are rare (WHO/HPA, 2011), Ahern *et al.* (2005) and Marcheggiani *et al.,* (2010) report that industrialised countries have shown increases in diarrhoeal disease among flooded populations. In their data analysis, Jakubicka *et al.* (2010) found that there have been outbreaks of some arbo-virus disease, West Nile Virus and leptospirosis following flooding in Europe. A full account of all diseases is out of the scope of this project but it is important that there is awareness of the endemic diseases already present the local area and also other possible diseases which may arise due to climate change and increases in extreme weather events (Medlock, 2011; WHO, 2005).

6.3.3 Communicable diseases can be transmitted if water is restricted for hygiene and food preparation (WHO/HPA, 2011; Sphere, 2011). In their research, Wade *et al.* (2004) reported that contact with floodwater was a much stronger risk factor for disease transmission than consumption (Wade *et al.,* 2004). The results of their interventional cohort showed the Incidence Risk Ratio (IRR) for gastrointestinal illness in adults of flooded homes was 2.36 times that of those in non-flooded homes . However, recall bias is considered likely since respondents filled in self reported diaries (Wade *et al.,* 2004). These results are in accordance with the retrospective cohort conducted by Reacher *et al.* (2004) who found the risk of gastroenteritis in a flooded home was 1.7 times that of non-flooded homes (Reacher *et al.,* 2004).

6.3.4 Tapsell *et al.* (2002) also found that there was a link between flooding and communicable disease. In their qualitative, retrospective study, many of those who volunteered information in focus groups reported, “diarrhoea, upset stomachs and feeling generally unwell” following flooding in England (Tapsell *et al.,* 2002).

6.3.5 The literature suggests that presence of illness need not necessarily lead to an epidemic and may lead to increasing incidences of isolated cases (Ivers *et al.,* 2006). Also, it was found people will often not contact their health provider for mild illnesses which could lead to an underestimation of the true morbidity than that reported to communicable disease departments (Smith *et al.,* 2006; Tapsell *et al.,* 2002).

6.3.6 During water shortage people may also turn to inadvisable alternative sources for water such as rainfall collection (Ahmed *et al.,* 2010; Rodrigo *et al* 2011). In Japan after the tsunami, young people were found to be getting diarrhoea from drinking river water in desperation (McCurry, 2011). These other sources may require further treatment than just boiling.

6.3.7 Bowen (2010) points out that the water and sewerage systems must be restored (following a disaster) in co-ordination because 'if you only restore water service, where does the wastewater go?'.

6.4 Mental health

6.4.1 Water shortages have been documented to cause panic, despair, feelings of exposure, distress and helplessness among affected populations (Pitt Review, 2008; Water UK, 2008; HPA, 2006; Gray *et al.,* 2006).

6.4.2 In their study, Rundblad *et al.* (2010) found that 85% of their sample who left their flooded homes did so mainly because of the difficulties of managing without mains water. When asked why this decision was made, a majority highlighted the fear of illness and vulnerability of their young children (Rundblad *et al.,* 2010). Of note, nobody within their sample stated loss of electricity or flooded home being their main reason for voluntary displacement (Rundblad *et al.,* 2010).

6.4.3 In his review of the flooding in England in 2007, Pitt (2008) found that a loss of water caused 'fear and helplessness'. Paranjothy *et al.* (2011) in their survey found that 'loss of essential services' such as water worsened mental health 'two to three fold'. This may have been exacerbated in the elderly, persons with disabilities, parents with small children, those without money or cars who could not get to water provision (CDC, 2011; Pitt Review, 2008). It has also been found that the elderly and disabled may have difficulty reading the water supply communication messages (Fuerst, 2006).

6.4.4 Impacts may be worse if people don't know what they should do or who will help them, especially if the situation is totally unexpected (Tapsell and Tunstall, 2008). Water supply may be reduced or cut off for substantial lengths of time (two weeks after onset of the extreme event (Zane *et al.,* 2010) and seven weeks after Hurricane Katrina (CDC, 2005).

6.4.5 Prolonged loss of water supply may induce population movement which can consequently exacerbate the health effects (Menne, 2010).

6.5 Vulnerable groups

6.5.1 Vulnerable groups are likely to be more affected than the general population during and after flooding and other extreme events. Vulnerable groups can be described as: those who are likely to have additional needs and experience poorer outcomes if these needs are not met (Nottingham Gov, 2008). It is strongly advisable to identify all possible vulnerable groups at risk in the planning stage for extreme event mitigation, with community involvement (WHO/HPA, 2011; CDC, 2011). This is stipulated in DEFRA's Security and Emergency Measures Direction 1998 (2008), but acknowledged that this may be difficult to undertake and other organisations may need to be contacted. This was discussed by delegates at the workshop, who stated that although some water companies have lists of vulnerable customers, these are voluntary (DWI/HPA Workshop, 2011). Other lists may be kept by Local Authorities, GPs, hospitals and voluntary organisations. Current systems for identifying, contacting and monitoring vulnerable groups were seen to be inadequate, however there also needs to be consideration for confidentiality and patient protection in the potential sharing of information (DWI/HPA Workshop, 2011).

6.5.2. It should also be borne in mind that communication messages regarding water provision must be tailored to reaching certain groups (Rudblad *et al.,* 2010) and handling may not reach vulnerable groups (Fuerst, 2006).

6.5.3 As the Pitt review highlights, when essential services such as water are cut off, everyone feels vulnerable and people who are not traditionally classed as vulnerable may become so due to a lack of access to alternative supplies (Pitt Review, 2008). Following the Mythe incident the rethinking of "vulnerable" to include (amongst others) babies, chronically sick, elderly and those not strong enough to carry water or able to get to water was highlighted in reports (Water UK, 2008).

6.5.4 During the Northern Ireland water shortage as a result of the freeze-thaw bursting of pipes and the flooding of Mythe, the Red Cross worked alongside the water companies and health services to facilitate the delivery of alternative sources to vulnerable individuals in affected areas (Utility Regulator, 2011; Water UK, 2008)

Table 1 illustrates a number of groups who will need specific consideration by water companies when distributing alternative supplies.

Table 1 – Vulnerable groups and individuals

GROUPS	INDIVIDUALS
Schools	Physically disabled
Prisons	Psychiatrically unwell
Nursing homes	Home kidney dialysis patients
Hospitals	Lone parents
Caravan parks	Homeless
Hostels and shelters	Non native speakers
Nurseries	Bottle fed babies
Transient populations	Elderly
Deprived Communities	Immunocompromised
Farmers (agriculture and animal farms)	Sick infants
	Cystic Fibrosis

(Tapsell, 1996; CDC, 2005; Water UK, 2008)

6.5.5 Children and infants are at an increased risk of dehydration due to the differing composition of body water, muscle mass and metabolic processes (Jequier *et al.,* 2010). Infants who rely on water to make up bottle feeds are especially vulnerable if the supply is interrupted for long periods of time.

6.5.6 The elderly also have differing body water volumes, muscle mass and metabolic processes to other adults and are more likely to suffer from chronic diseases which they may take medication for (Amella, 2006; Jequier *et al.,* 2010). Medication toxicity is an increased risk when dehydrated. In extreme heat episodes, the frail elderly populations are at an even higher risk of dehydration as they have a compromised sweating system, fewer sweat glands and a diminished sensation of thirst which can be a critical factor for heat related mortality if they do not maintain an adequate level of hydration. (WHO, 2004). A number of elderly persons live alone and during an extreme event may not be able to access supplies or carry heavy bottles and containers home. With a globally ageing population, water companies will need to ensure that the elderly and their associated contact groups are kept up to date on vulnerability registers in order to serve them quickly and effectively.

6.5.7 Those already hospitalised will be in greater need of clean water for drinking and sanitation but also medical procedures (WHO/HPA, 2011). The water shortage may be long term (Sinisi and Aergeerts, 2010), and the patients may have to be transferred.

6.5.8 Those with chronic diseases (such as renal failure or cystic fibrosis) at home or in care are more vulnerable when essential supplies such as water are cut off. For example clean water may be needed to sterilise medical equipment (WHO/HPA, 2011). Bethel *et al.* (2011) found in their analysis of a survey of six states that those with chronic illness were less likely to be prepared for a disaster, including having a 3 day supply of water. However, they were more likely to have a three day supply of medicines. If flooding is examined as whole, then chronic diseases can be made worse such as asthma, high blood pressure, heart attacks, kidney or other renal infections, joint stiffness and erratic blood sugar levels (Jakubicka *et al.,* 2010).

6.5.9 Those with language or communication difficulties may suffer a delayed response or misinformation due to communication barriers (WHO/HPA, 2011).

6.5.10 Research shows that those living in rural areas are more vulnerable to the effects of flooding and extreme events (Sinisi and Aergeets, 2010). The HPA also point out the dangers of using diesel, kerosene or propane driven devices to boil water in the home after flooding due to the risk of carbon monoxide poisoning (HPA, 2009).

7 Quantity

7.1 The quantity of water required is subject to the needs of the population following the event but there is still debate over the level of quality required (WHO/HPA, 2011).

7.2 The UN Economic and Social Council highlight the legal base of the right to water, stating that ***"The human right to water entitles everyone to sufficient, safe, acceptable, physically accessible and affordable water for personal and domestic uses. An adequate amount of safe water is necessary to prevent death from dehydration, to reduce the risk of water-related disease and to***

provide for consumption, cooking, personal and domestic hygienic requirements" (UN Economic and Social Council 2003, p2)

7.3 The Sphere project (internationally recognised guidelines into the minimum standards in disaster response) provides key actions, standards, indicators and guidance notes for emergency humanitarian response (Sphere 2011). They suggest a quantity of between 15 – 20 litres / person / day (hospitals = 40 – 60 litres / inpatient /day with more for other services such as laundry) to inform the immediate emergency phase with adequate provisions of supplies (Sphere 2011). They further recommend that people should not have to wait longer than 30 minutes for collection (Sphere 2011). However, it was unclear where the evidence base for these quantities and times is developed from. It is important to note that quantities utilised may differ between cultures, individual practices, traditions, habits, religion, coping mechanisms, and personal experience (Sphere, 2011). Also, people will have different requirement needs for example those with particular chronic diseases such as cystitic fibrosis (WHO/HPA, 2011).

7.4 Under the Security and Emergency Measures Direction (SEMD), water companies within the UK are required to provide by alternative means a minimum of 10 litres per day in the event of a supply failure. (OFWAT, 2007; Severn Trent Water, 2007). However, consumers used to an average daily consumption of around 138 litres/person/day obviously find adapting to this emergency volume very difficult as they must change their usage of water drastically (OFWAT, 2007; Severn Trent Water, 2007).

7.5 Reports from previous shortages found that companies and communications teams have found communicating emergency volumes difficult to explain and consumers have found the amounts hard to accept (Severn Trent Water, 2007). Following the Gloucestershire floods, and in response to recommendation 45 from the Pitt Report, Defra convened a Review of Alternative Water Supplies Group to examine increasing the amount of alternative water provided in an emergency and in December 2009 increased the amount to be provided to 20 litres / person / day after the first five days

(Water UK, 2008). Consumer feedback to the water company also reflected the need to increase the quantity above 10 litres (Severn Trent Water, 2007).

7.6 Twenty litres was also considered the maximum volume someone could carry and the potential indirect health effects that carrying heavy loads may have on an individual include musculoskeletal problems (Carmichael, 2011).

7.7. Due to the relatively more infrequent extreme events in Europe, populations are seldom encouraged to store water. However, in the USA, where extreme weather events are more common, populations are requested to have stored water from 3 to 14 days (Bowen, 2010). With climate change causing predictions of more severe and more frequent events, this advice may be appropriate for European populations as well, although there are issues of maintaining water quality (DWI/HPA Workshop, 2011). The CDC Guidance however has recommendations for keeping stored water at optimum quality (CDC, 2008).

8 Alternative supplies

(For a comprehensive outline of water quality and supply regulations the reader is referred to the complementary document 'Drinking water safety: guidance to health and water professionals' (DWI/HPA, 2009)).

8.1 Receiving supplies

8.1.1 Water Companies have a regulatory requirement to provide a safe alternate supply of water (which meets the requirements of the Water Supply (Water Quality) Regulations 2000 as amended) if the usual supply is disrupted. (DEFRA, 2008). Delegates at the workshop who were involved in the Mythe incident pointed out that the public were not aware of this obligation, and this caused a lot of confusion (DWI/HPA Workshop, 2011).

8.1.2 The Sphere Project (internationally recognised guidelines into the minimum standards in disaster response) advise alternative supplies be free from faecal coliforms (per 100ml) at the point of delivery and free from contamination (Sphere, 2011). In the UK SEMD directs water Companies to make provision for alternate supplies in the event of loss of normal piped drinking water. The Water Supply (Water Quality) Regulations 2000 as amended, set out the quality requirements for

England and Wales which any alternate supply provided by a water company must comply with.

8.1.3 Supplies can be delivered via,

- Rezoning water from other areas' piped supply (generally first choice for water companies)
- Transporting water between reservoirs
- Tankers
- Static tanks and bowsers
- Bottled water
- Stand pipes

(Consumer Council for Water, 2007; Water UK, 2008; WHO, 2010a; WHO, 2010b)

8.1.4 Tankers

8.1.5 Tankers or bowsers (mobile water units) are advised to be mobilised quickly to provide safe water of an approved quality (Water UK, 2008; WHO, 2011). Good organisation, rapid mobilisation of equipment, adequate human resources, predefined distribution points, regular filling, mutual aid agreements, preparation and practice runs are recommended to be incorporated into emergency planning in order to aid the prompt delivery of water and protection of public health (Water UK, 2008; Consumer Council for Water, 2007; WHO, 2011).

8.1.6 During the Gloucestershire floods (2007), vandalism of tankers (letting tap run, theft, urinating or introducing chlorine into tank) endangered public health and reduced the available stock from 1950 to 1500 (Consumer Council for Water, 2007). Reflective reports highlight the difficulty water companies face in providing a large number of distribution points while ensuring the safety of tanks with adequate human resources (Severn Trent Water, 2007)

8.1.7 Water companies have been advised to keep accurate documentation on designated distribution points and communicate this to the public as complaints of placement and access have led to confusion (Consumer Council for Water, 2007; Trewin, 2007). However, delegates from the workshop stated that the ability of any water company to accurately assess the impact of unplanned events on any water supply network is unavoidably subject to a range of unknown variables that characterise complex water

supply systems. These technically complex issues are difficult to communicate to Stakeholders and there is little or no tolerance for any perceived delay in translating accurate and timely information to affected Customers. The mechanisms for determining and accurately presenting the details of any impact on water supply through the Company's Customer interface facilities (e.g. websites and through customer relations centres) needs to be streamlined and speeded up. The capacity of these systems must also be expanded sufficiently to effectively handle the occasional extreme surges in demand that may be experienced during an extreme event (DWI/HPA Workshop, 2011).

8.1.8 Health messages indicating that water must be boiled after collection are advised to be clearly displayed on the exterior of the tank as although the water quality is assured within the tank, the containers people may transport it in may introduce contamination (DWI / HPA, 2009).

8.1.9 Bottled water

8.1.10 There are three types of bottled water available in the UK; "Spring Water", "Bottled Drinking Water" and "Natural Mineral Water". Spring and bottled drinking water are required under the European Standard Council Directive 98/83/EC to meet certain standards and therefore, are able to be used in the same way as mains water (Council of European Union, 1998). Natural Mineral Water is not required to comply with these standards but must meet previously agreed limits for several naturally occurring chemicals that could potentially negatively affect public health (Council of European Union, 1998). However, there is no limit for sodium in Natural Mineral Water and this has caused some concern and confusion in regards to making up infant formula during previous water shortage emergencies.

8.1.11 During the Gloucestershire floods, the Public Health Department advised infant formula to be made up using boiled and cooled bowser water since it is of approved quality (Trewin, 2007). The Food Standards Agency guidelines on water provision for bottle fed babies are in agreement with this and can be found in full on their website and that of the HPA (HPA, 2009) In their guidance, the HPA / FSA (2009) state that bottled water supplied by the water company should be safe and comply with European standards, but if from other sources, people should check that the sodium content (labelled "sodium" or "Na") is <200mg per litre.

8.1.12 Bowser and bottled water should be brought to a rolling boil and cooled for no more than 30 minutes before being used according to the manufacturer's guidelines (HPA, 2009). Other water should be sourced if the sodium level is found to be over 200mg and if this is not possible, the water should be used for as short a time as possible. Reiteration over the importance of keeping babies hydrated is made in the available guidance. However, workshop delegates pointed out that there is still some confusion over the issue of sodium content and bottle feeds and it should be clarified (DWI/HPA Workshop, 2011).

8.1.13 Logistical issues such as storage facilities, movement of large pallets of stock and plastic waste management need to also be considered (Santry, 2008; Whitely 2008). Severn Trent (Gloucestershire) also found that panic buying at supermarkets led to the need for crowd control by the army when distributing the bottles (Severn Trent Water, 2007; Trewin, 2007). It is also recommended that when involving 'third parties' in the provision of water to consumers during emergency situations, necessary checks and procedures are in place to ensure the water supplied is wholesome (Northern Ireland Environment Agency 2011)

8.2 Home treatment

8.2.1 In their research into water treatment techniques following hurricane related flooding, Ram *et al.* (2007) advise health bodies to increase the emphasis on home treatment (arguing that such techniques are not well enough understood). The WHO's guidelines on ensuring food safety in the aftermath of disasters can aid in the dissemination of advice on reasons for home treatment (WHO, 2010c).

8.2.2 <u>Boiling</u>

8.2.3 Boiling is the most common notice to be issued in a loss of supply situation (DWI / HPA 2009). Notices which may be issued are: 'Boil tap water before use';' Do not drink your tap water' and 'Do not use your tap water' (DWI / HPA, 2009). Water for use in baby formula should always be brought to a rolling boil and cooled for no longer than 30 minutes before use.

8.2.4 Boiling water ensures maximum risk reduction against disease (United States Environmental Protection Agency, 2006). However, boiling should only be performed if the public health authority responsible fears that the consequences of drinking

untreated water outweigh the risk from burns associated with boiling (Ram *et al.,* 2007). In their literature review the WHO/HPA found that boiling will kill bacteria and viruses etc but will not deactivate harmful chemicals (WHO/HPA, 2011).

8.2.5 Ram *et al.* (2007) found that in Louisiana, knowledge and behaviour regarding boiling required more input from health authorities (Ram *et al.* 2007). They showed that although 78% of their sample population knew that boiling could effectively treat drinking water, only 1 % of respondents knew how to do it correctly (Ram *et al.,* 2007). 52% of respondents thought that boiling was required over 5 minutes (Ram *et al.,* 2007). However, the study focused on a small population of those who had not self-evacuated, suggesting that those choosing to evacuate may have had different approaches to treating water, thus biasing results. Although care should be taken when applying results of this specific community to other populations, the results do offer important guidance into the communication needs regarding treatment of water in flooded populations.

8.2.6 Other experiences gained from case studies show that more health related information on ***why*** to boil water and what potential health consequences can arise need to be communicated for the public to fully understand and comply with advice (Water UK, 2008; Consumer Council for Water, 2007; Ram *et al.,* 2007; Fuerst, 2009; Rundblad *et al.,* 2010). Rundblad *et al*. (2010) found that a number of people, would continue to boil the water despite different notices requiring differing actions, for example ‘Do Not Drink’.

8.2.7 <u>Chlorination</u>

8.2.8 In less developed countries, home water treatment is often advocated even in the absence of extreme events and consequent water shortages (Firth *et al* 2010) If bottled water or boiling is not suitable, available or sufficient then the best measure is chlorination (WHO, 2005). It is cheap, widely available, effective, easy to use and inactivates close to 100% of bacteria (WHO, 2005).The CDC advises using household chlorine bleach at a concentration of 0.75ml / gallon of clear water and 1.50ml / gallon of cloudy water left for 30 minutes (CDC, 2010). It should be noted though, that certain parasites such as cryptosporidium can be resistant to chlorine (Wingender and Flemming, 2011).

8.2.9 Good communication of this method is essential as Ram *et al.* (2007) found 78% of their sample knew chlorination was an effective water treatment and 92% reported having bleach in the home prior to the hurricane yet only 2% knew the correct dose (Ram *et al.,* 2007). Over half of respondents thought more chlorine should be added, risking potential poisoning episodes (Ram *et al.,* 2007).

9 Communication

9.1 With the General Public

9.1.1 The Public Health Department's role in communicating precautionary measures and keeping the public informed of risks and updates on water provision is vital for health protection, public confidence and overall resilience (Menne, 2005; Penning-Rowsell *et al.,* 2005).

9.1.2 As Water UK state, ***"communication is the cornerstone of maintaining public health during a flooding event both to advise consumers what they can...and cannot drink and where to find potable water"*** (p20) (Water UK, 2008).

9.1.3 Transparent, honest, direct communication is vital between actors and with the public through their direct involvement (Menne, 2005; Gray *et al.,* 2006; Severn Trent Water, 2007). Ongoing communication utilising all available channels should underpin the day to day activities between water companies and health authorities to ensure a smooth and effective working relationship (Severn Trent Water, 2007; DWI/HPA, 2009). A pre-defined communication plan to facilitate this is suggested as an essential component within an emergency plan (Consumer Council for Water, 2007). UK Water and Severn Trent Water advise communication is accurate, consistent, up-to-date and takes into account disrupted communication channels, increased website and call centre needs, vulnerable consumers and potential lack of electricity (Water UK, 2007; Severn Trent Water, 2007). It was pointed out at the workshop that the public should be informed as early as possible what medium will be used to inform them about the water supply situation (DWI/HPA Workshop, 2011).

9.1.4 Word of mouth was cited as one of the most effective electricity independent routes of communication with 23% of Ram *et al.*'s (2007) sample having received information this way. However, they warn of the potential for incomplete, inaccurate information being spread and impress that more needs done to identify alternative effective communication channels. This is especially important for the socially

disadvantaged and ethnic minorities (WHO/HPA, 2011). They also found confusion was a problem when many different agencies produced their own advice, thus releasing conflicting messages simultaneously (Ram *et al.,* 2007). On reflection, Ram *et al.* (2007) suggest producing user friendly, pre-prepared texts containing information on treatment of supplies in easy to understand language(s) to minimise confusion and misinformation (Ram *et al.,* 2007). They also advised that home treatment procedures be incorporated into the overall emergency plan so public awareness is improved (Ram *et al.,* 2007). It was stated at the workshop that there would need to be strictly defined triggers for different levels of water provision measures, as advocating home treatment would certainly be a last resort (DWI/HPA Workshop, 2011).

9.1.5 Many other accounts of cases exist where information arrived too late, was of poor quality, questionable accuracy or conflicted between agencies which led to confusion and anger amongst the public (Consumer Council for Water, 2007; Tapsell *et al.,* 2002; Rundblad *et al.,* 2010). Contradictory advice is a risk to public health and therefore, it is advised that it is standardised and managed by one designated agency (Head *et al.,* 2009). Also it should be remembered that those from ethnic minorities and the disabled may have differing communication needs from the general population (WHO/HPA, 2011).

9.1.6 Alternative methods of communication as experienced from a number of case studies have been summarised in table 2.

Table 2 –communication methods

electricity dependant	electricity independent
television news bulletins	loudspeakers
radio - regional/national	word of mouth
call centres - 24hr (recorded messages and helpline)	notices in street
websites	posters in pubs, Health centres, shops, restaurants
internet blogs, social media, & forums	newspapers
television storylines	door to door leaflets
teletext	letters
Texting services	notices on tankers

(Sources: Pitt Review, 2008; Water UK, 2008; Consumer Council for Water, 2007; Severn Trent Water, 2007; Hedger, 2005)

9.1.7 Ram *et al.* (2007) showed that only 46% of mobile home residents had access to internet *before* hurricane Rita which would have implications on how the advice was disseminated *during* the shortage (Ram *et al.,* 2007). This same study reported that 77% of people in one community knew about boil water notices when the local manager made door to door visits compared to only 9% in another community who received no such visits (Ram *et al.,* 2007). Likewise, the DWI/HPA report advises local authority managers to make sure tenants in housing facilities have direct visits in case they have not received the information by other means (DWI / HPA, 2009).

9.1.8 During flooding in New Zealand, research into communication methods showed radio broadcasts were most favoured by the public with 41% of respondents receiving their information this way (Wilson *et al.,* 2005). Although newspapers (20%) were also a popular method of communication, only 9% of national articles relating to the flood mentioned health effects and only 3% mentioned water supply (Wilson *et al* 2005). Of those who requested more advice, 78% were looking for information on water safety (Wilson *et al.,* 2005). Although these findings have important public health significance, a low response rate of 76% indicates there is potential for non respondents to have differed in the way they accessed information and so results should be treated with caution (Wilson *et al.,* 2005).

9.1.9 Rundblad *et al.* (2010) also found that their UK based cohort preferred local radio as a source of information, however a USA based study found that people preferred telephone communication (CDC, 2011). Another study found that leaflets and door to door knocking was the most effective method (Ram *et al.,* 2007).This highlights that knowledge of the local community is vital to be able to get health messages across in the most effective way (CDC, 2011).

9.1.10 It has also been suggested that improved television usage with information bulletins at allocated time slots would benefit future emergencies (Consumer Council for Water, 2007), as would having nominated local 'disaster contact persons' if community and personal networks are strong (Rundblad *et al.,* 2010).

9.1.11 If utilising call centres, experiences have shown that they must be well resourced with specially trained staff who can give reliable and confident advice (Consumer Council for Water, 2007). In 2007, UK call centres were accused of being difficult to get through to, inconsistent in their advice, confusing and very expensive due to long periods of time on hold (Consumer Council for Water, 2007).

9.1.12 Regular contact with the community is essential to reassure alternative supplies will be provided, prevent false rumours of disease outbreaks spreading and keep people updated on when it is safe to return to their piped supply (Ohl *et al.,* 2000) It will also help to avoid panic buying and hoarding of bottled supplies unnecessarily as has happened in the past as a result of inadequate community communication (Water UK, 2008).

9.1.13 At the workshop, it was also emphasised that there should be some encouraging of individual resilience by the public such as having easily accessible tools for use in an emergency such as a torch and having stored water (DWI/HPA, Workshop 2011). Also, water companies could do some proactive informing of the public such as promoting the use of lagging to prevent water pipes freezing (DWI/HPA, Workshop 2011).

9.2 With the Media

9.2.1. Garnett and Kouzmin (2007) point out that the media can be 'both part of the solution and part of the problem at different times', and this was reflected by delegates at the

workshop. Articles regarding the media coverage of recent flooding events in England are currently being written, however delegates at the workshop expressed concern that information regarding water companies' work was often incorrect during extreme events, and that this hampered their recovery efforts.

9.2.3. Literature reviews of past events and disasters (natural and otherwise) show that news coverage tends to be extensive for the initial stages, but then rapidly fades as interest turns elsewhere (Kuttscheuter *et al*., 2011). However, interest may be renewed if a report on the disaster is published, or if there are prosecutions of individuals or organisations (Kuttscheuter *et* al., 2011). Often there are conflicting opinions as to what is relevant during an extreme event between the media and health (Barnes *et al*., 2008).

9.2.4. At the workshop it was emphasised that developing relationships with the media during periods of normal activity would be invaluable when emergencies arise (DWI/HPA Workshop, 2011). The media decide how to 'frame' an event (i.e. what aspects are to be highlighted), but the public and other stakeholders (such as water companies in this case) can influence this (Kuttscheuter *et al*., 2011; Garnett and Kouzmin, 2007). Establishing networks and relationships with the media before an extreme event may help each organisation understand each others roles (Barnes *et al*., 2008; Lowrey *et al.,* 2007). It may also ensure that during an extreme event, more accurate information is given out by the media, and that the water companies are portrayed in a more positive light in future extreme events. It can also avoid media-spread rumours (Garnett and Kouzmin, 2007). Water companies however need to ensure that the information that they give out is timely and accurate (Muller, 2010) and that they demonstrate leadership during a crisis (Littlefield and Quentte, 2007).

9.2.5. Other solutions to ensuring a mutually beneficial relationship with the media put forward by the literature include inviting journalists to drills and exercises, agreed communication channels, attending each organisations meetings and also not to depend on the mass media for all communication (Garnett and Kouzmin, 2007, Lowrey *et al.,* 2007)

10 Emergency response

10.1 Criticism has been made against uncoordinated responses to water shortage in the past with the public believing no emergency plan existed (Consumer Council for

Water, 2007). In order to restore trust and instil confidence, reflective reports advise emergency plans be made available for the public to see (Consumer Council for Water, 2007; Severn Trent Water, 2007; CDC, 2011). This would also highlight that water companies have preparations for emergencies and could also be used to advocate economic water usage (DWI/HPA Workshop, 2011).

10.2 The literature advises water provision to be built into emergency planning with water companies actively involved in their preparation (Bartrum *et al.*, 2009; Water UK, 2008). In 2007 Defra and the Welsh Government issued '*Planning for Major Water and Wastewater Incidents in England and Wales: GENERIC GUIDANCE'* . The Guidance was issued to water companies and LRFs in order to inform and enable planning to respond to an incident of a size that is beyond the response capability of a water company even with mutual aid from other companies, and where the planning and response required is likely to involve a number of agencies. In the annual SEMD audit it required companies to include statements that confirm companies' engagement (or otherwise) with Local Resilience Forums in planning for major incidents, which is a statutory obligation. In the event of a shortage, authorities and water companies should initiate their emergency plans quickly to provide rapid alternative supplies (WHO, 2005). The DWI urge them to consider the "3 P's" (p39) (Jackson, 2004) –

- **"P**lanning: Detailed risk assessment[2], vulnerabilities, emergency rehearsals, population needs and quantity estimations"
- **"P**reparation: Providing sufficient alternative supplies and coping with communication to public
- **"P**erformance: Reflection to learn from experiences"

(Jackson, 2004)

10.3 Coordination and communication is key in the emergency response with the literature advising all agencies to adopt clearly defined roles and responsibilities with a list of all those involved included in the plan to avoid response delays and confusion (Water UK, 2008; Terrugi, 2010; CDC, 2011). This includes a comprehensive Water Safety Plan by the Water Companies (Summerill *et al.,* 2010).

[2] A National Risk Assessment' (NRA) (Cabinet Office, 2008) exists to assess the relative likelihood and the impact of major risks to the United Kingdom. It provides a shared assessment of the relative significance of potential events that would cause significant harm and disruption.. Of the wide range of hazards identified at national and regional levels, water companies have been identified as the lead in the assessment of several water-industry specific risks as well as part contributors to several others (DWI/HPA Workshop, 2011).

10.4 Coordination of the emergency response has been found to be particularly difficult if the extreme event happens on a public holiday and if there is more than one weather condition to contend with (e.g. flooding and snow) (Tapsell and Tunstall, 2008). It was also pointed out at the workshop that companies need to consider the health and safety of their own employees if access to the WTW is difficult or if the workplace is unsafe (DWI/HPA Workshop, 2011).

10.5 Utilisation of estates teams in hospitals have also shown to be an invaluable resource to be incorporated into the emergency plan as they have expertise of the local infrastructure and how best to manage the response at the local level (Whitely, 2008; Chief Executive Gloucestershire Hospitals NHS Foundation Trust, 2007). It was highlighted at the workshop that some delegates had found that resilince of hospitals during periods of water shortage was not optimal (DWI/HPA Workshop, 2011). Water supply conservation and plans for alternative supply should be part of hospital business continuity plans and not fall on water companies to fulfil all their water needs (DWI/HPA Workshop, 2011).

10.6 Local authorities, emergency planners, water companies and public health professionals are advised to work together, share information and use systematic timely and up-to-date health advice which is synchronised in its guidance (Pitt Review, 2008; HPA, 2006; Menne *et al.,* 2005; McMaster and Baber, 2008). Severn Trent (Gloucestershire) created a health liaison post within the water company in recognition of this important communication role during a water emergency (Severn Trent Water, 2007). At the other end of the spectrum, the Chief Constable during the Gloucestershire floods created a Platinum Command to liaise with the Cabinet Office Briefing Room (COBR) (McMaster and Baber, 2008).

10.7 Use of the military during the 2007 floods was invaluable in the formation of logistical aid for the distribution of water (bottled and boswer) (WHO/HPA, 2011). However, it should be noted that the military can only be mobilised in specific circumstances by the Strategic Coordination Group (SCG) lead by the police and with approval from the Government and must withdraw their services at the earliest opportunity (Cabinet Office, 2010; McMaster and Baber, 2008).

10.8 It was found at the workshop that in order to enhance current emergency plans, there needs to be a greater reporting and sharing of experience and evidence regarding

water shortages between relevant organisations (for example reporting company 'near misses' as well as large scale emergencies) (DWI/HPA Workshop, 2011). Those who had previously experienced an extreme weather event were in a position to be better prepared than those companies who had not (DWI/HPA Workshop, 2011).

10.9 Enhanced Surveillance

10.9.1 This document has highlighted studies that have been performed following extreme weather events which have lead to the need to provide alternative supplies of water (e.g. Tapsell and Tunstall, 2008 and Pitt Review, 2008). However, no regulations or protocols currently exist regarding the need to conduct enhanced surveillance of the health impacts on the affected population during an incident affecting the water supply. Such surveillance may involve the HPA, Primary Care Trusts (PCTs), Clinical Commissioning Groups (CCGs) or Local Authorities.

10.9.2 Enhanced surveillance is usually implemented when a new disease emerges (such as the H1N1 swine flu (HPA, 2009b) and /or when more information is needed regarding the manifestation of the disease for developing prevention and mitigation strategies (Bradley, 2008). Mandatory enhanced surveillance by acute hospital trusts is performed for some infectious diseases such as Methicillin Resistant Staphylococcus Aureus (MRSA) (HPA, 2011a). Local Health Protection Units conduct enhanced surveillance for Legionnaires' Disease (HPA, 2010a) and E. coli O157 (HPA, 2008) as routine.

10.9.3 At present, during and following a major incident HPUs would monitor notifiable diseases (such as cryptosporidium (HPA, 2010b) to see if observed cases were more than expected and advise on mitigation measures, if required. A larger incident may require regional or national co-ordination.

10.9.4 NHS Direct can also be requested to perform enhanced syndromic surveillance for particular geographical areas using their current indicators and QSurveillance (GP weekly surveillance) may also be used in a prolonged incident (HPA, 2011b; Elliot, 2010). The indicators include diarrhoea and vomiting, eye problems and fever (HPA/NHS Direct, 2011). This would be in conjunction with the HPU Incident Management Team. Incidents where this has been done include the flooding in England in 2007 and the Volcanic Ash Cloud in 2010 (HPA, 2011b). There is a

possibility of adding further NHS Direct indicators in the short term but the algorithm would need to be worked out and agreed in advance.

10.9.5 Enhanced surveillance may be a method to ensure immediate health issues and problems caused by the extreme event are highlighted (such as communicable diseases) but also that the health impacts of the event are ascertained and monitored in a systematic and robust way. However, further work will be needed to determine which health indicators are to be surveyed, why, how and by whom.

11 Limitations of Report

11.1 Only English language papers and reports were consulted for this report and therefore, language bias has to be considered a limiting factor. A review of non-English documents from various European countries who have experienced extreme events and water shortages is advised so this guidance can be better applied and generalised more confidently.

11.2 Due to the lack of epidemiological studies found, the project relied heavily on grey literature which is not peer reviewed and is based on the opinion and experiences of individual organisations. However, local guidance, international resources and institutional reports are an extremely important tool within guidance formation and despite their inherent weaknesses within evidence based public health, they are seen as an essential component of this project.

12. Points for Consideration

12.1 Final points for consideration are presented in the following tables and separated by the themes previously identified and discussed. Grading as per the SIGN guidance has also been shown to highlight the level of evidence generated by each source.

12.2 Points for consideration with established and documented processes, protocols, roles and responsibilities

AREA	Status and Owner Organisation	Grading by SIGN Guidance
Emergency planning that includes		
• The planning for severe supply interruptions that exceed the duration and scale of routine operational events	In place with Water Companies and DEFRA (SEMD) (DEFRA 2008)	D
• A clear description of the roles of each organisation, agency, individual, voluntary group or team that will respond	In place with Water Companies and DEFRA (planning for Major Water and Waste water Incidents in England and Wales Generic guidance 2006)	D
• Identification of alternative sources of water and any early changes in their quantity and quality (Aergeerts, 2010)	Water Companies through Regulation 27 risk assessments. The Water Supply (Water Quality) Regulations 2000 as amended.	D
• Responses that are able to be activated remotely and should not depend on the emergency team having to access buildings or roads that may be cut off by flooding/snow or windstorm damage.	DEFRA, DWI and Water Company contingency plans	D
• An understanding of how extreme events can impact on services, showing the management and mitigation of these risks.(Ofwat, 2007)	Water Companies through Regulation 27 risk assessments. The Water Supply (Water Quality) Regulations 2000 as amended	D

AREA	Status and Owner Organisation	Grading by SIGN Guidance
Emergency planning that includes (cont…)		
• Involvement of the community and supermarkets in formulation of plans and engagement with Local Resilience Forums	Local Resilience Forum Water Industry and Local Resilience Forums (LRFs)- see http://www.cabinetoffice.gov.uk/sites/default/files/resources/vulnerable_guidance.pdf	D
• **Quantity**		
• A statement about the minimum quantity of water required per person after an extreme event. Currently, the sphere standards state the minimum quantity of water to provide should be 15 – 20 litres / person / day to allow for drinking and essential hygiene activities (Sphere 2011). In the UK it is 10 litres and after five days, 20 litres is strongly recommended (Ofwat, 2007; Water UK, 2008)	SEMD guidelines – guidance 6.	C
Quality		
• Advice to the public that water from tankers is advised to be boiled to avoid secondary contamination. Duty of water companies to oversee supplies.	Duty of water companies to oversee supplies. Code of practice (BS8551) is due to be published. Provision and management of temporary water supplies and distribution networks (not including provisions for statutory emergencies).	D
Communication		
• Pro-actively inform stakeholders on the importance of protecting water pipes during cold weather and their own responsibility	Through water industry websites and other communication	D

12.3 Points for consideration which may not currently be adopted across all stakeholders

AREA	Status and owner organisation	Grading by SIGN Guidance
Emergency planning that includes		
• Training and practice exercises in water delivery in extreme events to include the use of large sized vehicles and identification of which roads could be suitable to travel on.	Government, DEFRA and Water industry exercises	**D**
• Allowing communities to view plans to strengthen relationships and build trust.		
• Identifying all possible vulnerable groups at risk from water shortage	Water Company will liaise with Local Authorities	
• Consideration for the indirect public health effects of using many tankers on roads and the carrying of heavy containers		D
• The description of activities and actions required in the event that critical sites and / or infrastructure become unavailable due to an extreme event (Aergeerts, 2010)		D
Alternative Supplies		
• The possibility of military involvement to support mobilisation and assist secure distribution of supplies, although with due consideration to the criteria for their deployment.	Military Aid to the Civil Community (MACC) or Military Aid to the Civil Power (MACP) requested by SCG.	**D**
• The supervision of tankers, where feasible, to avoid vandalism, aid filling and allow dispersal of important health advice and information in person. Category 1 responders could assist if operational needs arise.		**D**

AREA	Status and owner organisation	Grading by SIGN Guidance
Communication		
• Advice that is easy to access and understand, incorporating a range of languages. It should be pre-prepared and ready to be disseminated immediately	Water Companies have established plans for use of notices.	D
• A statement that the aim of communication about health impacts should be diversity in delivery but consistency in content.		D
• One designated agency leading on advice delivery where possible. . Volume of advice being delivered should be controlled to avoid overloading the public with too many messages at once.	Water Companies Lead on communications about the water supply. This will feed in any external response structure eg LGD, Gold	D
• Advice incorporating the health related reasons *why* consumers are being asked to perform techniques such as boiling and also information on avoidance of burns and carbon monoxide poisoning. Generic FAQs should be developed in partnership		D
Vulnerable Groups		
• Extensive use of the third sector to help the authorities in the distribution of water, particularly for those who are unable to leave their houses or carry heavy loads.	Local authorities co-ordinate the activities of the various sector agencies and spontaneous volunteers.	D
• In a protracted event, communication regarding possible unsuitable alternative water sources and potentially unsafe methods of boiling water.	Bouchier Report DWI website	D

12.4 Points considered where further work is recommended

AREA	Status and owner organisation	Grading by SIGN Guidance
Vulnerable Groups		
• During and following an extreme event there must be monitoring of those classed as vulnerable to ensure that they are gaining access to sufficient safe clean water, particularly the elderly.	Recommendation for further consideration – HPA to lead in conjunction with other Health Professionals	D
• Review of literature to ascertain evidence base to assure communication on advice for infants requiring bottle feeding are receiving bottled water with the correct sodium content.	HPA and partner organisations researching to provide evidence base.	D

12.5 Research and areas for future development

Quantity
• The quantity of water required by populations after an extreme weather event requires future research. Reflections from case studies have shown that this may need to be revised.
Vulnerable Groups
• The requirements during water shortages by vulnerable populations need to be further researched.
Documenting & Publishing Events
• Grading of evidence needs to take account of the fact that during extreme events, it is not possible to conduct studies at the higher end of the research hierarchy. Case studies, grey literature and reflective reports from actual events are an extremely valuable method of identifying lessons for future events.
Health related studies
• Explore the need for an agreement between Health Protection Agency and Primary Care Trusts/Clinical Commissioning Groups to undertake appropriate enhanced surveillance of the health of the affected population during and after an extreme weather event, to include the development of "how to" protocols relating to enhanced surveillance, health and water shortages • Professional development of health sector staff in water related information should form part of their routine training • Enhanced surveillance undertaken in extreme weather events to be formally documented and written up for publication where applicable

13. Conclusion

13.1 Given the recent projections on climate change and the future impacts it will have on extreme events, it is clear that European preparedness, response and recovery within public health and water shortages is essential. Recent reports of water shortages as a result of extreme events affect significant numbers of people and have highlighted the need to build robust, coordinated plans which are based on scientific evidence.

13.2 It has been advised that emergency plans need to go beyond the daily failures of supply and prepare for events which may cut off water to a large number of consumers for over 24 hours and involve more than one water company (DEFRA/Welsh Assembly Government, 2007). It also needs to be taken into account how the extreme event will affect logistics of distribution, the health of the population without supplies and how these periods will differ from day-to-day shortages. Extreme events can all affect health independent from water shortage and this is to be taken into account when planning alternative supplies.

13.3 It is also important that water companies and health professionals work together and acknowledge the needs of vulnerable populations, who will require help and why certain groups of people may be more susceptible to adverse health effects as a result of water shortages.

13.4 During the first workshop it was suggested that this document be updated and revised on an annual basis. The aim of this will be to identify and incorporate published evidence, scientific literature and the lessons identified from events that will take place after publication of this initial document. It was also advised that regular seminars with water companies and health protection experts be conducted each year to update the document with any future advice.

13.5 Finally, it has been shown that the research in this area needs to be built and expanded on. Although the SIGN guidance categorises most of the literature as a level D, it is recognised by the research team the value that these company reports and reflective documents bring. Due to the nature of disasters, their inherent unpredictability and the immediacy required of the response it is often not possible to undertake rigorously pre-planned randomised control trials. However, expanding the

scientific literature and making the opportunity to conduct research in this field is essential for the future knowledge base and developing our resilience.

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APPENDICES

1. **APPENDIX A - Literature review methods**
2. **APPENDIX B - Keywords used in literature search**
3. **APPENDIX C - Literature search algorithm**
4. **APPENDIX D - Literature review search results**
5. **APPENDIX E - SIGN guidance and evidence grading**
6. **APPENDIX F – Definitions of extreme events**
7. **APPENDIX G –Table of extreme event impact as a consequence of climate change**

APPENDIX A - Literature review methods

1. Keyword matrix

A keyword matrix was developed using the **four key concepts** within the research question and their synonyms.

- **Flood** (e.g. inundation)
- **Water shortage** (e.g. water access)
- **Public health** (e.g. dehydration)

Synonym truncation was applied to increase retrieval and account for spelling differences (e.g. flood***** for floods *and* flooding. Organi**$**ation for organisation *and* organization)

2. Peer reviewed literature

Databases were searched using the keyword matrix including Medline, Embase, Global Health and the Cochrane Collaboration. Limits were set to “English” “2005 – current” and “human”.

3. Further Searches

Retrospective

Reference lists of relevant papers were hand searched to identify pertinent articles missed on initial database search.

Prospective

Retrieved articles were prospectively searched using Web of Science citation search.

Author

Articles were searched by the project team to retrieve similar work.

Specific Journals

Advanced search of specific journals including The Journal of Water and Health.

4. Exclusion / inclusion criteria

1. Papers initially were kept if titles indicated study on water and health
2. Abstracts of retained papers were reviewed and the following exclusion / inclusion criteria applied

Inclusion criteria

- Water shortage &
- Emergency public health responses &

Exclusion criteria

- African and Asian countries - responses of these countries cannot be confidently extrapolated to our European setting due to differences in underlying endemic disease, adaptability, vulnerability, coping mechanisms, infrastructure and culture.

5. Unpublished documents

Contact was made directly with the relevant personnel in the HPA and DWI to yield their yet unpublished guidelines and reports.

6. Grey Literature

The following sites were searched directly using the same inclusion and exclusion criteria

- WHO (regional office for Europe and International sites)
- Centre for Disease Control and Prevention (CDC)
- HPA
- Food Standards Agency (FSA)
- Google
- Google Scholar
- Drinking Water Inspectorate (DWI)
- UK Water
- Consumer Council for Water
- Environment Agency (USA and UK)
- Department for Environment Food and Rural Affairs (DEFRA)

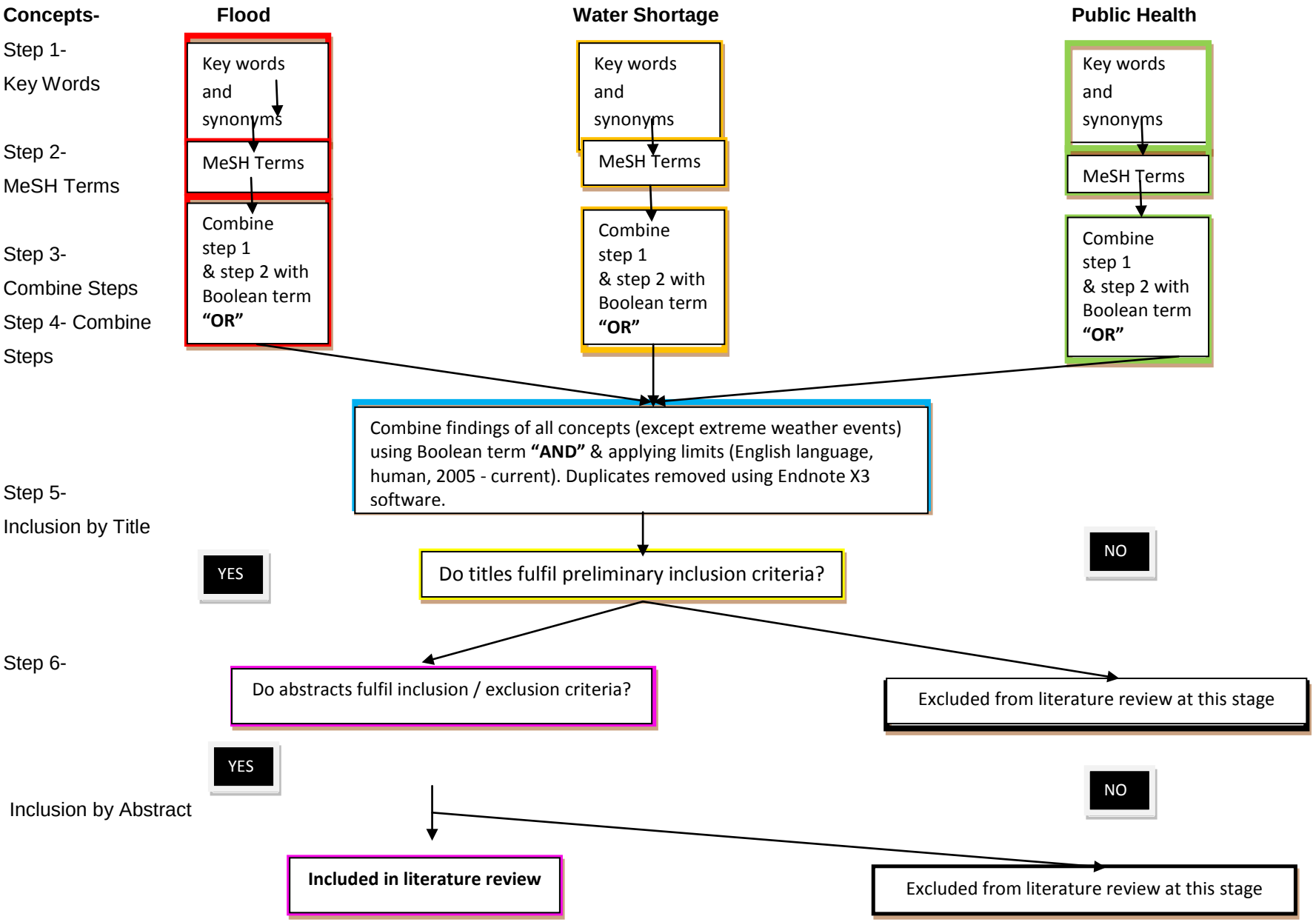
2.1.2. Key words and Literature Search Algorithm

See Table 1 and Figure 1.

APPENDIX B – Keywords used in literature search

Concept	FLOOD	WATER SHORTAGE	PUBLIC HEALTH
synonyms	flood* OR rain* OR precipitation OR flood damage* OR flash flood* OR inundation* OR river flood* OR sea flood* OR flood warning* OR hurricane OR major flood* or submerg* OR flood barrier OR flood-barrier OR floodbarrier OR tidal OR deluge OR flood risk	water shortage* OR water-shortage* OR water treatment* OR water access OR bottled water OR drink* water OR availab* water OR water OR consumable water OR potable water OR consumption OR drought OR water restriction*	Public health OR infection* OR infectious* OR illness* OR disease OR communicable* OR diarrohea* OR diarrhea* OR hepatitis A OR fever OR gastrointestinal OR waterborne OR water borne OR water washed OR waterwashed OR water carried OR watercarried OR contaminat* OR burns OR dehydration
	MeSH term- Flood, disaster, emergency	MeSH term- water supply	MeSH term- public health

APPENDIX C - Literature search algorithm



APPENDIX D – Literature review search results

TITLES RETRIEVED	RETAINED AFTER TITLE SEARCH	RETAINED AFTER ABSTRACT SEARCH	ADDITIONAL & HAND SEARCHES
661	96	20+4	24

Retained papers utilised a range of study designs and all discussed drinking water shortage, public health responses and / or the health related outcomes following flooding.

APPENDIX E - SIGN guidance and evidence grading

It is generally accepted that guidelines for aspects of both medical and public health should always be based on available research evidence. However, in order to adequately demonstrate that the evidence available has been assessed for quality and that the recommendations are being put forward based on that quality assessment, a system is required. This is why the SIGN Guidance was developed (SIGN 2011).

Primarily SIGN is recommended for the development of clinical guidelines, but since it is being recognised that non-clinical guidance needs to be evidence-based, SIGN can be used for non-clinical guidance.

In this instance, due to time limitations, the principles of the SIGN guideline development system will be used. The basic system is that a literature review is undertaken, and relevant articles and studies are selected. These are then assessed for quality and given a grading (see table 1 in Appendix A). Subsequent recommendations and guidance developed as a result of these articles and studies are then also graded depending on the initial grading of the studies (see table 2 in Annex A).

For guidance for emergencies and disasters, due to the nature of the situation, the research evidence is highly unlikely to be that considered to be the highest research level (i.e. systematic reviews and randomised controlled trials). As can be seen from the literature available, most are so-called ‘grey literature (incident and case reports). Although the SIGN system does make some allowances for this (Harbour and Miller 2001), subsequent recommendations and guidance, although extremely valid for the evidence available, are generally marked towards the lower end of grading (C or D in table 2). However, from this recommendations can be made for the conduction of future research.

SIGN Grading for Literature Review Articles

Table 1

1++	High quality meta-analyses, systematic reviews of RCTs, or RCTs with a very low risk of bias
1+	Well conducted meta-analyses, systematic reviews, or RCTs with a low risk of bias
1 –	Meta-analyses, systematic reviews of RCTs with a high risk of bias
2++	High quality systematic reviews of case control or cohort studies High quality case control or cohort studies with a very low risk of confounding or bias and a high probability that the relationship is causal
2+	Well conducted case control or cohort studies with a low risk of confounding or bias and a moderate probability that the relationship is causal
2 –	Case control or cohort studies with a high risk of confounding or bias and a significant risk that the relationship is not causal
3	Non-analytic studies, e.g. case reports, case series
4	Expert opinion

SIGN GRADES OF RECOMMENDATION

Note: The grade of recommendation relates to the strength of the evidence on which the recommendation is based. It does not reflect the clinical importance of the recommendation.

Table 2

GRADE	***EVIDENCE***
A	At least one meta-analysis, systematic review, or RCT rated as 1++, and directly applicable to the target population; or A body of evidence consisting principally of studies rated as 1+, directly applicable to the target population, and demonstrating overall consistency of results
B	A body of evidence including studies rated as 2++, directly applicable to the target population, and demonstrating overall consistency of results; *or* Extrapolated evidence from studies rated as 1++ or 1+
C	A body of evidence including studies rated as 2+, directly applicable to the target population and demonstrating overall consistency of results; *or* Extrapolated evidence from studies rated as 2++
D	Evidence level 3 or 4; or Extrapolated evidence from studies rated as 2+

(SIGN, 2011)

APPENDIX F – Definitions of extreme events

1. **Flooding**

a. Definitions and warnings

Flooding has been defined by the Pitt review (independent inquiry into UK flooding emergency 2007) as a ***"temporary covering by water of land not normally covered with water"*** *(*p458) (Pitt Review, 2008). Flooding can be categorised into the following five types whose individual characteristics include velocity, area flooded, speed of onset and duration (Ahern *et al.,* 2005)

Flash flooding – little warning with a high speed of onset (Ahern *et al.,* 2005)

River flooding - Occurs when a watercourse cannot cope with the water draining into it from surrounding land. This can happen when heavy rain falls on an already waterlogged catchment. Warnings are issued by the Environment Agency (EA) for river breaches, which may be from a hundred metres to a few kilometres in length (Environment Agency, 2009)

Groundwater flooding - Groundwater tends to flow from areas where the ground level is high, to areas where the ground level is low. During very wet periods, the water table can rise up to the surface causing groundwater flooding. The response times are slower compared to other forms of flooding and as such advance warning of more than 5 days are possible through the EA. (UK Groundwater Forum, 2011)

Surface water flooding - Usually associated with high intensity rainfall events (typically >30mm/h) but can also occur with lower intensity rainfall or melting snow where the ground is saturated, frozen, developed or otherwise has low permeability resulting in overland flow and ponding in depressions in the topography.
Forecasting flooding from surface water is particularly challenging since it typically occurs a few hours or even minutes after a period of intense rainfall, the lead time for issuing warnings is very short.. As this form of flooding is usually the result of convective rainfall, forecasting the occurrence and location of rainfall events is notoriously difficult (Natural Environment Research Council, 2011)

Coastal flooding - Results from a combination of high tides and stormy conditions. If low pressure coincides with a high tide, a storm tide may happen which can cause

serious flooding. Meteorological forecasts of these events are reliable up to 5 days ahead (Environment Agency, 2009)

Reservoir flooding. 'Some reservoirs hold large volumes of water above ground level, contained by walls, or 'dams'. Although the safety record for reservoirs is excellent, it is still possible that a dam could fail. This would result in a large volume of water being released very quickly'. (Environment Agency, 2009).

Land use changes leading to an increase in the areas at risk from flooding, a reduction in available water storage capacities and increased runoff coefficient include;

- Deforestation
- Soil erosion
- Urbanisation increases areas of hard paved surfaces, sealed areas and reduction in ground surface area to absorb water).
- Building on flood plains

(Sinisi and Aergeerts, 2010; Foster, 2010; Khadjibayev, 2005; Menne, 2005)

b. Relationship to water shortage

Direct inundation of flood water into essential unit processes, pumping stations or water treatment works (WTW) can result in the necessary shutdown of operations and subsequent cessation of supplies to consumers if the company are unable to rezone the area supplied onto an alternative supply. (Foster, 2010; Water UK, 2008). There could also be an increase in demand from flooded local areas, operational equipment failure at the WTW and flooding of intake systems (Foster, 2010). Flooding can inundate electricity supply stations rendering them unable to provide WTW with power.

In a recent study reviewing preparedness and response to flooding between 2000 and 2009 in 50 of 53 countries in the WHO Regional Office for Europe, drinking water shortages were reported in the following 11 countries: Armenia, Bosnia and Herzegovina, Croatia, Georgia, Hungary, Macedonia, Republic of Moldova, Slovenia, Tajikistan, UK/England and Wales, Ukraine (HPA/WHO, 2011). The problem of water shortages during and after a flood is clearly a significant consequence of flooding with the potential to afflict serious secondary health effects from the flood.

c. Case study examples

In 2007, direct flooding of the Mythe WTW in Gloucestershire (UK) resulted in a complete shutdown of the facility. Mythe was the single source of water for 350,000 consumers who were cut off from a piped supply for 15 days (Water UK, 2008). The biggest deployment of equipment since World War II was required to deliver the necessary volume of alternative supplies to the affected population (Water UK, 2008). 1950 bowsers were deployed to 1100 locations and 3 million bottles of water were distributed a day (Water UK, 2008). The flooding also affected 5 other WTW to varying degrees resulting in the partial or short term shutdown and interruption of supplies to consumers (Sinisi and Aergeerts, 2010; Foster, 2010; Water UK, 2008).

Emergency provision of alternative supplies was required in Hungary when severe flooding inundated and contaminated groundwater. There were 3673 cases of gastrointestinal illness and 161 people were hospitalised as a result (Dura *et al.,* 2010).

2. Cold Weather

a. Definitions and warnings

Cold Weather - There is no formal definition, but in the UK, the Met Office define severe winter weather as occurring when one of three condititions arise. These can occur independent of each other or simultaneously:

1. A mean temperature of 2 ˚C or below for 48hr or more
2. Widespread ice
3. Heavy snowPredicting a trend to cold weather can be achieved at monthly timescales. Freezing rain, glazed frost or widespread icy roads alerts issued 5 days in advance with warnings issued 24 hours ahead

Snow - Solid precipitation which occurs in a variety of minute ice crystals at temperatures well below 0C but as larger snowflakes at temperatures near 0C. The Met Office will issue a national severe weather warning if snow is predicted to fall at a rate of at least 2 cm/hour or more for at least two hours. Subtle changes in atmospheric conditions can lead to sudden change of weather; snow, ice or rain. For this reason, warning for snow can be difficult. Alerts issued 5 days in advance with warnings issued 24 hours or more ahead (Lewis, 1991).

b. Relationship to water shortage

Cold weather can affect water systems directly through freeze-thaw causing the potential for mass damage to the supply network, bursting of pipes and damage to water treatment plant (Utility Regulator, 2011; Foster, 2010). Performance of the WTW can be impacted and operational failure can result from freezing at abstraction

sites (Utility Regulator, 2011; Foster, 2010). Biological and chemical processes can be reduced with pipes supplying chemicals more likely to freeze and internal mechanical valves are also more prone to freeze and automatically shut down treatment processes. Outdoor equipment such as sand filters can fail as a result of low temperatures and open surfaces of water can freeze (Foster, 2010). Large volumes of snowfall can lead to operational failure of the abstraction systems and WTW or failure of electricity supplies due to power cable damage (Foster, 2010; Utility Regulator, 2011).

c. **Case study Examples**

In 2010, Northern Ireland experienced one of the coldest winters for over 100 years resulting in wide spread bursting of domestic and commercial pipes due to freezing followed by thaw (Utility Regulator, 2011). Over 450,000 consumers were interrupted from the mains supply and reservoirs were depleted as demand exceeded supply by 20% in an effort to maintain pressure and delivery within the system (Utility Regulator, 2011). The practical effects of a rapid thaw on the scale of this event are as follows:

- In pipes close to the surface and directly affected by frost, typically private supplies, the water within the pipe may have frozen causing the pipe to burst.
- A rapid thaw, over 24-48 hours, can be likened to 50,000 domestic taps being switched on at once, with resultant rapid changes to flow and pressure characteristics in the distribution network.
- The cumulative effect, applied over such a short period of time on already weakened water mains can exacerbate the number of bursts and will in any event cause a substantial rapid increase in demand.
- In addition, a steep temperature gradient, in the range 15-20 degrees, causes rapid ground movement around watermains as the ice melts.
- This induces longitudinal pipe fractures as external load pressure is released quickly or splits around the circumference of the pipe caused by differential ground movement and thermal expansion.
- Overall a rapid thaw results in significantly less time to manage the detection and isolation of leaks which leads to the depletion of water storage in service reservoirs.

Large amounts of snowfall in Western Hungary during the winter of 2009 caused damage to power cables due to the weight of the snow. The subsequent electricity failure affected 34 settlements and 89,000 consumers when the power was interrupted to pumps and equipment of both water supply facilities who lacked

sufficient back up generators (Compiled by representatives of the National Institute of Environmental Health, Hungary cited in Foster, 2010). Water tankers were deployed to provide alternative supplies and boil water notices were issued.

3. Extreme heat

a. Definitions and warnings

Although there is no universally accepted definition of heat waves these are understood to be periods of unusually hot dry or hot humid weather that have an insidious onset and cessation, a duration of at least 5days leading to a discernible impact on human and natural systems (World Meteorological Organization, 2010)
In the UK, a Heatwave is defined when the daily maximum temperature of more than five consecutive days exceeds the average maximum temperature by 5°C. The normal average period of 1961–1990 corresponds to the UKCP09 baseline period. England and Wales, a Heat-Health Watch system operates from 1 June to 15 September each year. This comprises four levels of response based upon threshold maximum daytime and minimum night-time temperatures. These thresholds vary by region. Warnings are issued 2-5 days in advance of a heat wave

b. Relationship to water shortage

During a heatwave, water quantity may have to be carefully controlled and usage by consumers will increase due to consumption and leisure activities in hot weather. There may also be restrictions and prioritisation of supplies required (Foster, 2010)

4. Drought

a. Definitions and warnings

Droughts are natural events and happen when a period of low rainfall leads to a shortage of water. A different type of drought is the psychological or agricultural drought whereby moisture is in the soil but little is getting to vegetation, either because it is frozen (which can occur in severely cold winters in the UK) or because of very high temperatures which means that the rate of evapotranspiration is exceeding the rate of uptake of water from the plant. Seasonal and monthly water availability trend predictions and associated hydrological induced drought risk are now possible.

Droughts can further increase the risk of wildfires (Sinisi and Aergeerts, 2010).

b. **Relationship to water shortage**

Drought can affect the entire water system from source to consumption and this needs to be taken into account in a water companies advanced planning and forecasting measures (Foster, 2010). Periods of drought reduce available supplies and also increase demand in domestic and agriculture settings (Foster, 2010). Water companies will need to be aware of reduced pressure in networks leading to increased risks of infiltration and contamination of water already in the system and malfunctioning of treatment systems following long extended periods of drought (Foster, 2010). Within the context of the UK, the water resources management plans that have previously been discussed will take into account the actions required by water companies during a drought. These are a statutory obligation of water companies within the UK.

5. **Wildfires**

a. **Definitions and warnings**

Often referred to as Forest, Moorland, Grass and Heath fires. Fires can flare up without notice during or following a protracted heat-wave and often triggered by lightning or man made incidents. Fire requires fuel, oxygen and ignition. In the context of outdoors, the fuel is vegetation - fine, medium and coarse. In order for vegetation to become fuel, it needs to be cured (dried) which is weather related. Dead vegetation is excellent fuel, particularly if it's cured during the warm season. Ideal curing conditions are; no rain, strong winds, low humidity, warm temperatures. These parameters can be predicted days ahead with 24 hour site specific warnings possible once the fire has started.

b. **Relationship to water shortage**

Most case reports and commentaries relate to Mediterranean, and other vulnerable areas of the world. A specific case study summarising the effects of wildfire leading to drinking water shortage has not been identified although several with wider water shortage have been found.

6. **Windstorms**

a. **Definitions and warnings**

Non-tropical cyclone; atmospheric pressure distribution in which there is a low central pressure relative to its surroundings. It is characterised on a synoptic chart by a system of closed isobars, generally approx circular or oval in form, enclosing a central low pressure. Tropical cyclone; formed over tropical or sub-tropical waters

with organised convection and a definite cyclonic surface wind circulation. A tropical cyclone of moderate intensity is a 'Tropical storm'; if of great intensity, a tropical cyclone. Called a tropical cyclone in the Indian Ocean, Cyclone in Arabrian Sea or Bay of Bengal, Typhoon in western Pacific and Willy-Willy in Western Australia and in most other tropical latitudes a Hurricane. (Lewis, 1991). Designated warning centres using observational data and weather models are able to predict tropical cyclones for up to several days ahead. For non tropical cyclones, alerts are issued 5 days with warnings issued with lead times of 24 hours or more (Lewis, 1991).

b. **Relationship to water shortage**

Infrastructure damage, operational failure of the water treatment and / or abstraction works and electricity cuts can all result from windstorms. Contamination of wells and local surface water can occur due to sea water intrusion as a consequence of high winds (Foster, 2010).

c. **Case study example**

Before Hurricane Katrina struck in August 2005, New Orleans had a largely poor and African American population. The aftermath of Katrina devastated the New Orleans population and changed the city's health care landscape and leaving many without access to care a year after the storm. Immediately following the storm, evacuees reported that they had spent time trapped in homes; living on a street or an overpass; and enduring harrowing and stressful conditions, often lacking food, fresh water, prescriptions, and medical care (Rudowitz *et al.,* 2006)

7. **Landslides**

a. **Definitions and warnings**

A landslide is defined by Cruden (1991) for the Working Party on World Landslide Inventory as *a movement of a mass of rock, earth or debris down a slope*.

There are five kinematically distinct types of landslide identified by Varnes (1978)

a) ***Falls:*** A fall starts with the detachment of soil or rock from a steep slope along a surface on which little or no shear displacement takes place. The material then descends largely by falling, bouncing or rolling.

b) ***Topples:*** A topple is similar to a fall except that it involves the forward rotation, out of the slope, of a mass of soil or rock about a point or axis below the centre of gravity of the displaced mass.

c) ***Slides:*** A slide is the downslope movement of a soil or rock mass on a distinct slide or shear surface. These can be rotational or translational depending

on the geology, structure and hydrogeology. Rotational slides involve a semicircular shear surface. Translational slides usually occur on planar slip surfaces.

d) ***Flows:*** A flow is a spatially continuous movement in which shear surfaces are short lived, closely spaced and usually not preserved after the event. The distribution of velocities in the displacing mass resembles that in a viscous fluid.

e) ***Spreads:*** lateral spreading is characterised by the low-angled slopes involved and the unusual form and rate of movement. A spread is an extension of a cohesive soil or rock mass combined with a general subsidence of the fractured mass of cohesive material into softer underlying material. The rupture surface is not a surface of intense shear. Spreads may result from liquefaction or flow (and extrusion) of the softer material.

However, Varnes (1978) also presented a sixth mode of movement, Complex Failures. These are failures in which one of the five types of movement is followed by another type (or even types). For such cases the name of the initial type of movement should be followed by an "en dash" and then the next type of movement: e.g. rock fall-debris flow (WP/ WLI, 1990). In reality, almost all landslides involve more than one type of movement either concurrently in different parts of the failure or evolving downslope over time into different failures. Very difficult to predict with little or no warning given.

8. Algal blooms

a. Definitions and warnings

Harmful Algal Blooms include Cyanobacteria (blue-green algae), which grow in any type of water and are photosynthetic (use sunlight to create food and support life) and are natural inhabits of inland fresh water bodies including lakes, rivers and reservoirs They usually are too small to be seen, but sometimes can form visible colonies, called an algal bloom usually green or blue-green in colour. Cyanobacteria have been linked to human and animal illnesses around the world, including North and South America, Africa, Australia, Europe, Scandinavia, and China. (CDC, 2004).

b. Relationship to water shortage

Most common exposures are believed to occur during recreational and occupational contact with cyanobacteria in lakes, rivers and marine waters. Acute, chronic, and episodic exposures may arise from drinking water, dietary intake via consumption of cyanobacterial toxin–contaminated foods and dietary supplements

c. Case study examples

A Bloom of cyanobacterium “Planktothrix rubescens” occurred a 13km wide artificial Italian reservoir during 2009. The Algal density exceeded 150 million cells/litre and affected supplies to 800,000 consumers. The immediate response included risk and health communication to the local population and mitigation of toxin presences in drinking water (Foster, 2010).

9. Earthquakes

a. Definitions and warnings

The vibrations of the earth caused by the passage of seismic waves radiating from some source of elastic energy (Bolt, 1998). The vibrations often stem from fault lines which are fractures or zones of fractures (zones of weakness) in rock along which the two sides have been displaced relative to each other parallel to the fracture (Bolt, 1998). A measure of earthquake size is determined by the Richter scale. Common types of magnitude are: Richter (or Local) magnitude (M_L), Moment magnitude (M_W) and Surface wave (M_S). There is still no reliable way to predict earthquakes accurately despite many years of research internationally, but statistics and geological knowledge can indicate where large earthquakes are likely and what their effects will be. Near real-time, 24-hour, seismic monitoring and information services are in operation.

b. Relationship to water shortage

Exercise Golden Guardian (2008) was carried out in the USA though a 7.8 richter scale earthquake along the San Andreas fault. They found that pipes would break leading to contamination of potable water with sewage and that water would also have to be used to fight fires caused by the earthquake (Bowen, 2010).

10. Tsunami and tidal surge

a. Definitions and warnings

Tidal Surge – Tidal watercourses such as the Thames river in London are at risk from tidal flooding. Global warming and the resulting rise in sea levels will increase this risk.

Tsunamis – Although tsunamis do not commonly threaten the UK coastline, they have caused severe water shortages in other countries and therefore, their acknowledgement in this document is intended to aid understanding. They are caused by underwater earthquakes, landslides (above and below water) and volcanic eruptions. They can cause devastation in low-lying areas when they reach

the shore. Major tsunamis are most commonly produced by large (greater than 7 on the Richter scale).

11. Volcanic Eruption

a. Definitions and warnings

A volcano is an opening in the earths crust that allows magma to reach the surface. An eruption can be characterised by a high, convective column in which most of the eruptive mass is ejected and results in atmospheric ash dispersal or a Bomb, in which a mass of magma more than 64mm in maximum dimension is largely plastic when erupted (Bardintzeff & McBirney, 2000). Although there is no universally accepted method of prediction, a number of volcanoes that pose significant threat to populations have been studied and risk assessments made. Volcanic ash predictions are available with 2-5 day forecast plumes issued from ICAO designated Volcanic Ash Advisory Centres.

APPENDIX G –Table of extreme event impact as a consequence of climate change

Intergovernmental Panel on Climate Change (IPCC). Special Report on Emissions Scenarios (SRES) Emissions Scenarios Data Set Version 1.1. New York, NY: Cambridge University Press. Available at http://www.ipcc.ch/pdf/special-reports/spm/sres-en.pdf

Table SPM.3. *Examples of possible impacts of climate change due to changes in extreme weather and climate events, based on projections to the mid- to late 21st century. These do not take into account any changes or developments in adaptive capacity. The likelihood estimates in column two relate to the phenomena listed in column one. {Table 3.2}*

Phenomenon[a] and direction of trend	Likelihood of future trends based on projections for 21st century using SRES scenarios	Examples of major projected impacts by sector			
		Agriculture, forestry and ecosystems	Water resources	Human health	Industry, settlement and society
Over most land areas, warmer and fewer cold days and nights, warmer and more frequent hot days and nights	*Virtually certain*[b]	Increased yields in colder environments; decreased yields in warmer environments; increased insect outbreaks	Effects on water resources relying on snowmelt; effects on some water supplies	Reduced human mortality from decreased cold exposure	Reduced energy demand for heating; increased demand for cooling; declining air quality in cities; reduced disruption to transport due to snow, ice; effects on winter tourism
Warm spells/heat waves. Frequency increases over most land areas	*Very likely*	Reduced yields in warmer regions due to heat stress; increased danger of wildfire	Increased water demand; water quality problems, e.g. algal blooms	Increased risk of heat-related mortality, especially for the elderly, chronically sick, very young and socially isolated	Reduction in quality of life for people in warm areas without appropriate housing; impacts on the elderly, very young and poor
Heavy precipitation events. Frequency increases over most areas	*Very likely*	Damage to crops; soil erosion, inability to cultivate land due to waterlogging of soils	Adverse effects on quality of surface and groundwater; contamination of water supply; water scarcity may be relieved	Increased risk of deaths, injuries and infectious, respiratory and skin diseases	Disruption of settlements, commerce, transport and societies due to flooding: pressures on urban and rural infrastructures; loss of property
Area affected by drought increases	*Likely*	Land degradation; lower yields/crop damage and failure; increased livestock deaths; increased risk of wildfire	More widespread water stress	Increased risk of food and water shortage; increased risk of malnutrition; increased risk of water- and food-borne diseases	Water shortage for settlements, industry and societies; reduced hydropower generation potentials; potential for population migration
Intense tropical cyclone activity increases	*Likely*	Damage to crops; windthrow (uprooting) of trees; damage to coral reefs	Power outages causing disruption of public water supply	Increased risk of deaths, injuries, water- and food-borne diseases; post-traumatic stress disorders	Disruption by flood and high winds; withdrawal of risk coverage in vulnerable areas by private insurers; potential for population migrations; loss of property
Increased incidence of extreme high sea level (excludes tsunamis)[c]	*Likely*[d]	Salinisation of irrigation water, estuaries and fresh-water systems	Decreased fresh-water availability due to saltwater intrusion	Increased risk of deaths and injuries by drowning in floods; migration-related health effects	Costs of coastal protection versus costs of land-use relocation; potential for movement of populations and infrastructure; also see tropical cyclones above

Notes:
a) See Working Group I Table 3.7 for further details regarding definitions.
b) Warming of the most extreme days and nights each year.
c) Extreme high sea level depends on average sea level and on regional weather systems. It is defined as the highest 1% of hourly values