RESEARCH AND INNOVATION MAPPING STUDY FOR THE UK WATER RESEARCH AND INNOVATION FRAMEWORK

REPORT REF. NO. 11/RG/10/6

Programme Area & Reference	**Regulatory: Innovation in Water RG/10**
Report Title	**Research and Innovation Mapping Study for the UK Water Research and Innovation Framework.**
Project Management	**Richard Kirby, on behalf of UKWIR**
Collaborators	**UKCDS, LWEC**
Contractor	**University of Surrey, Surrey Water Innovation Research Learning (SWIRL)**
Sub-Contractor	**Tony Rachwal & Associates**
Authors of Report	**Chenoweth J,** **Farrow J,** **Godfrey L,** **Griffiths M,** **Hatcher K,** **Heathwaite A.L,** **Hills S,** **Jenkins A,** **Khu S-T,** **Morse S,** **Pedley S,** **Rachwal A,** **Robson K,** **Rogers C,**
Report Type	**Final**
Period Covered	**2011**

Published by UK Water Industry Research Limited
1 Queen Anne's Gate, London SW1H 9BT

First published 2011

ISBN UKWIR USE ONLY

Printed by Webree.com Ltd.

UK WATER INDUSTRY RESEARCH LIMITED

RESEARCH AND INNOVATION MAPPING STUDY FOR THE UK WATER RESEARCH AND INNOVATION FRAMEWORK

Executive Summary

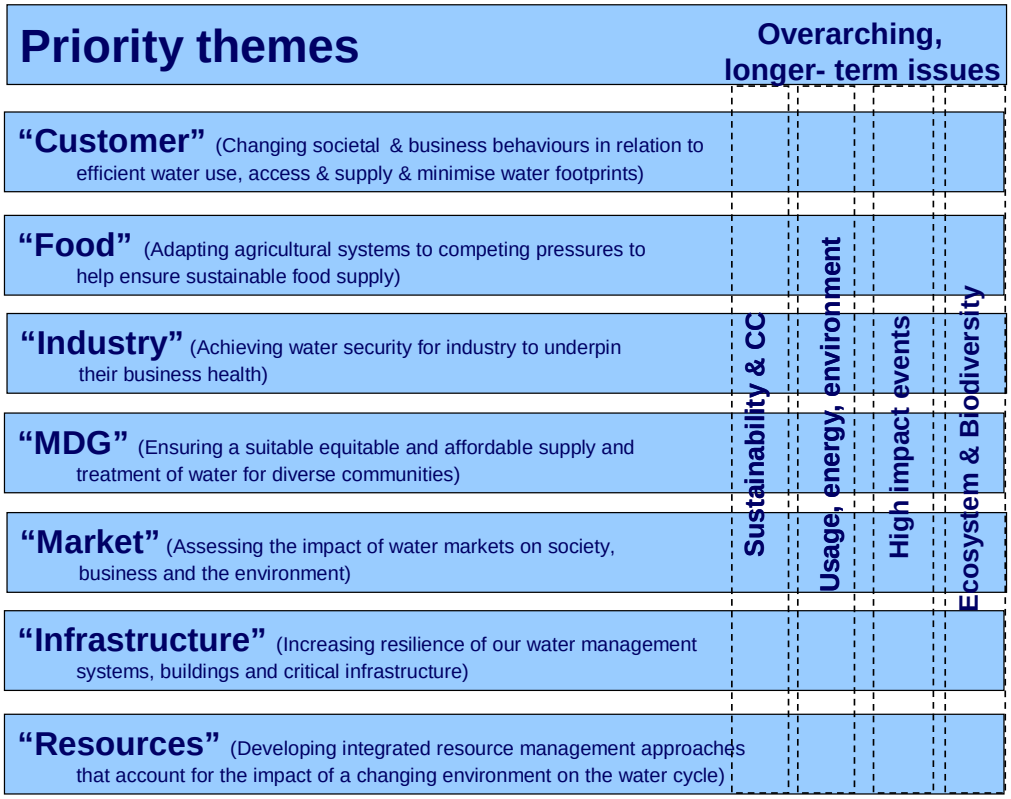
Project Brief/Objectives

As part of work towards a UK Water Research & Innovation Framework (UKWRIF), UK water experts were asked to carry out a high level overview and synthesis of recommendations from key policy and research reports relevant to the UK's potential contribution to UK and global water security. This was to be in the form of a mapping study under 11 agreed key priority themes related to water security (Figure 1).

Methodology

A team of 14 water experts from industry and academia followed an agreed methodology to review 90 identified relevant reports from a variety of respected sources including government, regulators, water industry, professional and research institutions, under the required themes (see Figure 1).

Figure 1 – Mapping Study inter-relating themes



Results

Overall the primary reports were of good quality, generally well-researched and cross-referenced (e.g. Cave & Walker) with a variety of evidence and case studies. However prioritisation of hard recommendations and future research needs were limited, so have been

supplemented by the views of the review team. The 6 key findings from the reports, related to the requested themes around water security, are as follows:-

1 Water is not "valued" correctly

Water is not currently valued correctly by stakeholders; this is a major problem in itself and also contributes to misuse. It is vital to develop a value framework for water resources from an end-user and environmental ecosystems perspective, and this needs to encompass the inextricable link between water and energy. Most of the UK population do not know their domestic water usage or the extent of their much larger water footprint, which includes "virtual" water embedded in food, industrial products and other services that may originate from other countries.

Reported value recommendations include ensuring universal metering and links to smart metering and tariffs (as in the energy sector), investigations of new models, such as water trading and changes to abstraction licensing, and better customer engagement and education. However the review team recommend taking this further, with more holistic initiatives such as creating a valuation framework to cover the range from negative value (polluted water) through neutral (seawater) to a positive value (high quality natural freshwaters) and methodologies to value virtual or embedded water. Models that have been successful in changing understanding and behaviours for carbon and landfill could be followed.

2 The resilience of UK water infrastructure requires better understanding

A changing climate and growing population will bring significant challenges to UK and global water infrastructure. Development of a resilient UK water infrastructure requires better understanding of societal behaviours (and their potential for change) and customer acceptable and affordable service levels. Leakage, bursts and sewer collapses from ageing, buried, urban water and sewerage networks may reflect the need to improve asset planning and that investment levels may be insufficient to prevent deterioration of the UK pipe network asset base. This may lead to future service problems. There are complex interdependences in these infrastructures, which could be improved using probabilistic scenario modelling and addressing priority vulnerabilities.

Recommendations include developing innovative community scale, city scale and regional solutions. This should include providing cost effective solutions for private water supplies. Ensuring "smarter" assets requires more accurate location, condition, performance and deterioration rate assessments of buried urban infrastructure. This includes multi-utility infrastructure, street-works, traffic and natural environment interactions. Designing new, long asset life, infrastructure, that can adapt to provide resilience to potential future climate change impacts, requires further development of cost benefit and risk methodologies. The UK has the potential to grow exports for enhanced infrastructure asset management in global markets.

3 There is a need to further address risks from water-related natural hazards

The risk of flooding from sewers, storm-water runoff, rivers, coastal surges and ground-waters for domestic, industrial (and to a lesser extent, agricultural) property and occupants is considered the greatest high-impact, natural hazard to the UK. Adaptation to climate change will require improved design parameters and predictive models of water availability (water scarcity) and the frequency and scale of extreme events (droughts and floods). It is necessary to also consider the impact of water-related natural hazards (floods, droughts, water borne disease vectors) to international regions providing or competing for global food and critical industrial supply chains important to the UK. China is identified as a priority for water

security risk and potential impact assessment on UK as well as potentially the largest UK market opportunity for consulting and design service based solutions

It is important to note that the current research into climate change modelling is unlikely to make a step-change in knowledge around the uncertainties within the next decade, so we have to act on what we know now.

4 Integrated water resources management tools are essential and must become more dynamic

Integrated river basin or water resource management frameworks incorporating needs, inputs and outputs from the natural ecosystem, agriculture, industry and urban domestic customer are recognised as increasingly essential. This includes setting of regulatory goals (EU Water Framework Directive), monitoring and operational management of all aspects of the water cycle within a catchment. The UK has some recognised leadership in this, building upon the 1974 Water Act, creating multi-functional river basin water authorities and subsequent regulatory frameworks for a privatised water utility sector. However, national strategic water resource investment and management may be sub-optimal as capital return financial incentives may be favouring strategic water resource solutions within, rather than across, current river catchment and commercial boundaries.

There is also a belief that current UK quality regulation, set to protect aquatic environments for infrequent adverse conditions, leads to higher energy and chemical usage at wastewater plants than desired from a sustainability and cost perspective. Research into more dynamic regulatory, modelling and management control frameworks is required including development of more affordable and resilient quality and performance monitoring. Innovative new water resources may be required including more energy-efficient wastewater treatment solutions, reuse of effluents and more energy-efficient desalination options.

5 The issues of water security in developing countries need to be addressed more rigorously, particularly in relation to the Millennium Development Goals

Water is recognised as a “fundamental human right”. Developing countries and external support agencies need to demonstrate greater political commitment to sanitation and drinking water, targeting resources to accelerate progress towards meeting identified Millennium Development Goals. Progress towards sanitation goals are significantly behind safe drinking water provision. 25% of all people in Africa experience water stress, mainly a problem of distribution. Effective, strategic, decision-making is hampered by insufficient or inadequate hydrological, quality and health risk data. In developing countries the relationship between irrigation and food production is generally more important than in the UK. It is noted that China is a major investor in extracting natural resources from Africa with high potential impact on water security and quality.

Recommendations include more strategic commitment and communication at government, financial and aid agency level. The UK could better deploy its recognised skill base in monitoring, remote sensing and modelling to provide key data needed for strategic decision making. Priority should be given to supporting education and capacity building, in country to develop affordable, deliverable and sustainable water and sanitation solutions. Developments in irrigation, conservation and safe re-use of water are essential to food security. Some questions for the UK include: does the recent E-Coli problem in Germany indicate water related risks for wider food production and should the UK focus international aid mainly on

water and sanitation in Africa with a potential partnership with China to engage UK and international aid agencies and NGOs?

6 Research and commercial opportunities from addressing Water Security

Review of the reports highlighted a number of approaches to identifying future research direction to address water security issues. However these appeared to be un-integrated and disparate. A requirement to work towards a more holistic methodology for research identification and prioritisation was identified by the review team. This not only helps towards ensuring a more resilient UK position in respect to future water security but also provides commercial opportunities for UK business. Overseas water markets, estimated at $500bn are particularly important for the UK consultants, contractors and supply chain. However there is a recognised skill shortage in the UK water industry which also needs to be tackled.

Conclusions and Recommendations

There is a clear need to establish a framework for joint innovation action across the water sector. Leadership is an issue. It is suggested that time-limited action frameworks are established to precisely define objectives and delivery programmes and to oversee funding mechanisms in the priority areas of need identified in this report. Membership may include: water utilities, regulators, academia, NGOs, consultants, contractors, and supply chains**.**

Investment in reported research in the UK water utility sector has fallen from £45m to £18m or 0.7 to 0.3 % of turnover in the past decade. It is suggested that investment in research and innovation across the whole UK water sector should be 1-2% of potential capital and operating expenditure, more typical in the UK engineering and production sector. This would imply a UK wide, innovation investment need of between £200m and £500m over a 5-7 year period, to make a significant impact by 2030 on delivery of improved water security in a rapidly changing environment. This should also support increased export opportunity, particularly in the service and infrastructure technology management sector increasing UK economic growth in the current £500bn, and forecast £770bn, global water market.

There is an increasing concern in water security and need for innovative and affordable solutions, evidenced by the volume of recent published reports reviewed in this study. The issues are complex and cover a wide range of political, social, environmental and technical challenges. Water security in the UK is significantly impacted by our imported, global water footprint and is inextricably linked to food and energy security and long term urban planning. A UK framework providing leadership and direction for delivering research and innovation in the 6 priority sectors identified in this report is recommended to increase UK water security and economic growth opportunities in the global water market.

Contents **Page Number**

1 Project Brief

As part of work towards a UK Water Research & Innovation Framework (UWWRIF), the LWEC directorate, in collaboration with UKCDS and UK water experts were asked to develop a framework to optimise the impact of UK research investments on water security at both national and global scales.

One of the activities to help develop the UKWRIF is the production of a mapping document of key reports, reviews and recommendations on water research and innovation relevant to UK and global water security. The brief, which is included in more detail in Appendix 1, was to carry out a high level overview and synthesis of recommendations from key policy and research reports (excluding academic journals) relevant to the UK's potential contribution to UK and global water security and to build on the substantial amount of mapping and foresight work previously undertaken by others.

The output was to be a high-level document of no more than 10-20 pages (plus annexes of supporting information), mapping the findings and recommendations of prominent water research and innovation reports relevant to UK and global water security from various sources. This report comprises that output.

2 Methodology

A master resource list of recent, non-academic reports, books and literature was identified (Appendix 3) and acquired for review and analysis against a matrix of priority themes and overarching, longer-term aspirations provided in the client brief (Appendix 1) and illustrated in Figure 2.

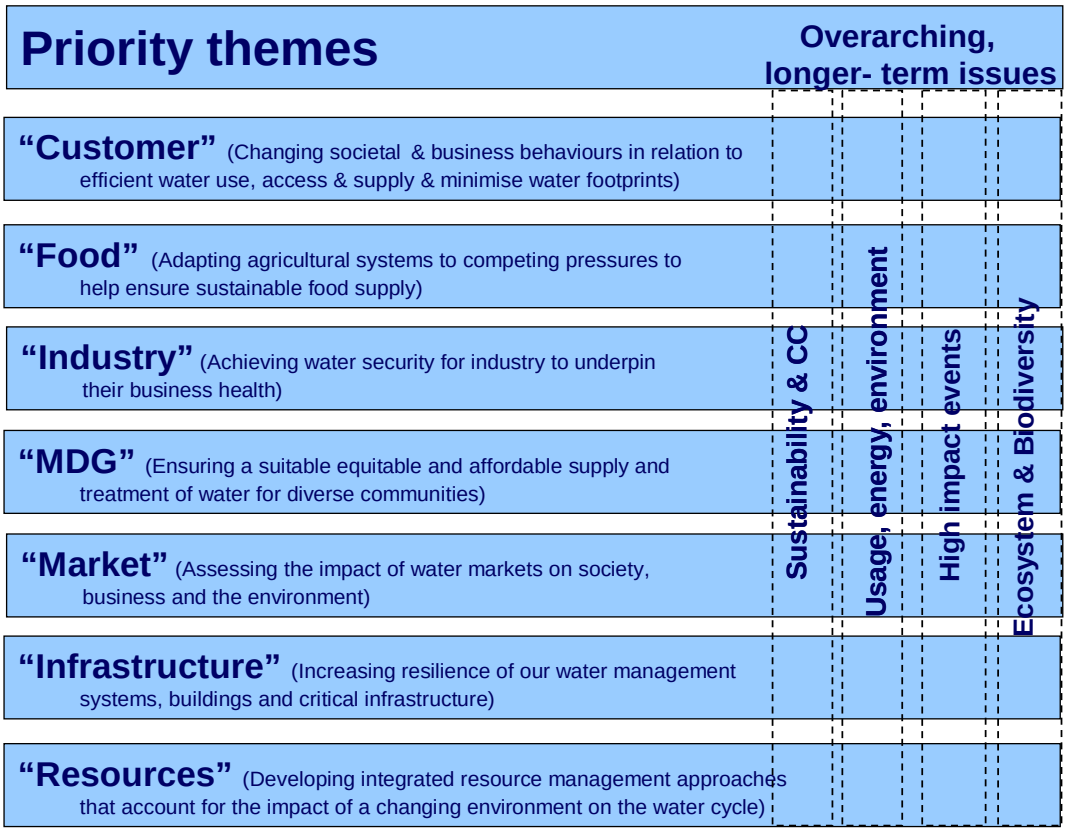
A planned source list of circa 30 reports rapidly expanded to a potential 909 reports (References section 6 and Appendix 3) as expert reviewers identified a larger than expected level of recent major report publications. This may reflect the increasing global concern on water security, following recent linked concerns about food and energy security. A prioritisation of the master resource list, based on institutional "weight" of the source authorship, originality of the content, apparent relevance to the UK and either breadth or focus on key issues, resulted in a "primary evidence" resource list of 47 reports and a "secondary evidence" list of 43 reports.

A consortium of 14 expert reviewers with water related, utility, regulator, customer communication, industry and academic expertise (Appendix 2) contributed to the review, analysis and synthesis process. In the first phase of the review process, each priority theme was assigned to teams of 2 or 3 reviewers, to individually read and note key primary and secondary evidence reports, with an example shown in Appendix 4.

A second phase of the review process merged theme group views, recording consensus or diversity of view on identified strategic issues, risks, opportunities, evidence, enablers, barriers and need for innovation, trials and longer-term research. These 2-3 page consolidated outputs, on the 7 priority themes and 4 overarching topics, are presented in Appendix 5.

The third phase of the review process was to analyse and synthesise key findings creating a key findings table (Section 3) and suggested activity maps with reviewer's comments for further action (Section 4).

Figure 2 Matrix approach to segmenting literature review and analysis



Authorship of "non-academic" reports was broadly categorised as government sourced, regulatory, utility, industry, financial/consulting, learned/professional institution, NGO, research funding/delivery or "other". Examples of major primary evidence reports, with full reference in the master resource list (shown as (No.)) are:-

"Government" – Future Water, Defra (2009) (18)

"Regulatory" – Review of Competition and Innovation in Water, Cave (2009) (2)

"Utility" – A Road Map of Strategic R&D Needs to 2030, UKWIR (2007) (8)

"Industry" – CDP Water Disclosure 2010 – Global Report, ERM (2010) (64)

"Financial/Consulting" – Charting Our Water Future, McKinsey & World Bank (2009) (3)

"NGO" – Vision 2030: Resilience of Water Supply and Sanitation, WHO (2009) (29)

"Research" – UK National Ecosystem Assessment, LWEC (2011) (72)

3 Results –Key Findings

	Evidence	References	Brief recommendations/key comments from reports	Reviewer's synthesis comments
1	**Water is not "valued" correctly**			
	Water is recognised as a 'fundamental human right'. Water is currently not valued correctly by stakeholders; this is a major problem in itself and contributes to misuse. Most UK domestic customers do not know how much water they use or their individual water footprint. Industry has started to report on water security but has limited knowledge of supply chain water footprint or security.	(2, 3, 4, 6, 7, 17, 18, 24, 25, 30, 32, 33, 41, 57, 64)	Recommendations include water trading, unbundling, abstraction licence trading, water saving messages, universal metering with smart meters and tariffs, advice to customers and better promoted efficiency initiatives. Behavioural change from many stakeholders (eg customers and businesses including water companies) was necessary. Many reports looked at customer per capita demand (148 litres per day) rather than overall water footprint (3,400 litres per day) representing water embedded in food and other products. There is a strong link between security of food, energy and water; carbon and water are embedded in food production, carbon is also embedded in water and water is embedded in energy Putting the customer first is key, and water-saving messages and advice to customers should be stronger and more consistent and water efficiency initiatives more promoted (linked to energy saving) incentivised and organised It was recognised that globally overall water footprints would increase as countries developed eg with changing diets and increasing industry needs. Also social attitudes to water, and hence value, vary across cultures. There should be more water recycling and reuse or all water types	Water is often seen as a free resource, having little or no intrinsic value, both as a resource and at point of use Water footprint needs to develop similar level of importance to carbon footprint To safeguard security, raw water in particular should be valued taking account of location, volume, availability, quality and needs. More holistic initiatives such as creating a valuation framework to cover the range from negative value (polluted water) through neutral (seawater) to a positive value of (high quality natural freshwaters) and methodologies to value virtual or embedded water. Consider non-conventional (arts and humanities) communication routes to the public to recognise and engage with the emotional value of water in our lifestyle choices and appreciation of

	Evidence	References	Brief recommendations/key comments from reports	Reviewer's synthesis comments
			(See also Appendix 5 thematic reviews: "Customer", "Industry", "Market")	personal value of our environment.
2	**The resilience of UK water infrastructure requires better understanding**			
	There are risks in respect of UK water infrastructure – in terms of both its resilience and its ability to cope with increasing demands and challenges	(5, 6, 7, 10, 18, 28, 45, 52, 53, 60, 64, 74, 75, 82)	The capacity, quality and resilience of UK infrastructure directly impacts growth and competitiveness in the global economy. Ageing infrastructure in the UK is a growing risk. Properly targeted investment is needed in ageing, buried water and sewerage assets and in process treatment plants Infrastructure planning, including community scale solutions, requires better understanding of changing societal behaviours and service levels acceptable and affordable to customers. Need to work in new ways to plan, design and maintain infrastructure and enable innovative solutions underpinned by integrated, multi-utility and urban planning. Need for new technologies and modelling and "smarter assets" improvements in understanding accurate location, condition, performance and deterioration rates of buried urban infrastructure including multi-utility, traffic and natural environment interactions. Need for reduction in the carbon footprint of both constructing and operating water and wastewater infrastructure. Energy positive wastewater treatment and low carbon desalination should be longer-range, infrastructure research objectives. Need for new technologies that can be retrofitted to existing assets to improve resilience, efficiency and capability to cope	Academia and providers of innovation should recognise that improving knowledge and management of existing and ageing infrastructure will have far greater impact in the UK over the next 30 years than investment in completely new infrastructure. New water infrastructure solutions will have a greater potential impact where first time urbanisation is growing rapidly e.g. China, India, Brazil and Africa. Need for smarter technologies to access repair and install buried infrastructure with minimal disruption to busy city streets. Need "ultra-low powered or self powered sensors and ultra-low maintenance, long life cycle (10+ years) sensors for measurement and control particularly for buried assets and whole river basins. Affordable, innovative solutions

	Evidence	References	Brief recommendations/key comments from reports	Reviewer's synthesis comments
			with increasing demands, due to population growth increasing consumption and potential impacts of climate change. (See also Appendix 5 thematic reviews: "Infrastructure", "Resources", "Industry", "Usage, energy & environment", "High impact events")	are required to address the potentially huge investment challenges of providing flood protection, sustainable drainage, combined sewer overflows and appropriate separation of rainfall and sewerage
3	**There is a need to further address risks from water–related natural hazards**			
	Floods are seen as the most important natural hazard in UK and Europe and will be exacerbated by intensive land use and uncontrolled urbanisation. Prolonged, large scale droughts are the second most important water related natural hazard in the UK and perhaps the greatest hazard to our international food supply chain.	(4, 18, 28, 49, 39, 45, 60, 64, 76, 81, 82)	Floods are the most important natural hazard across Europe in terms of both economic and life loss. The balance between water demand and availability has reached a critical level (water scarcity) in many areas of Europe (SE England). In addition, many more areas are adversely affected by changes in the hydrological cycle and precipitation patterns (droughts). In the past 30 years impact of droughts increased by 20%, affecting 11% of EU population, 17% of land area and cost impacts of circa 100 billion euros. Need to develop integrated land use planning and flood risk infrastructure, together with better predictive modelling capabilities and improved engineering and infrastructure options Severe flooding can also impact on water and energy supplies (Tewksbury, Fukishima). Location of current and future large energy generation assets is inextricably linked to consideration of natural water hazards including, river or coastal flooding, droughts, risks of quality contamination and	Flooding is not just a UK or European issue – eg serious flooding in China could affect agriculture (China is the world's largest grower and consumer of wheat) or key components of our industrial supply chain. Low probability but potentially high impact natural events such as tsunamis, new water borne disease vectors and major volcanic dust contamination of water resources, should receive further scientific risk assessment and appropriate response plans developed. There is a critical gap in prediction of regional or catchment scale weather events linked to jet stream variations and blocking highs which may lead to or terminate

	Evidence	References	Brief recommendations/key comments from reports	Reviewer's synthesis comments
			cooling water heat impact on natural water ecosystems. Affordable, innovative solutions are required to address the potentially huge investment challenges of providing flood protection and sustainable drainage. (See also Appendix 5 thematic reviews: "High impact events", "Resources", "Infrastructure", "Industry", "Sustainability and climate change")	prolonged droughts, extreme rainfall and temperature events. Better prediction of starting or ending events in the 30 days to 3 years time frame is required to improve operational planning and selection of effective responses. The current research into climate change modelling is unlikely to make a step-change in knowledge around the uncertainties within the next decade, so we have to act on what we know now
4	**Integrated water resources management tools are essential and must become more dynamic**			
	Integrated river basin or water resource management frameworks incorporating needs, inputs and outputs from the natural ecosystem, agriculture, industry and urban domestic customer are recognised as increasingly essential	(2, 3, 6, 18, 39, 48, 52, 53, 60, 64, 76, 77, 78, 79, 80, 81, 82)	The UK has some recognised leadership in this, building upon the 1974 Water Act, creating multi functional river basin water authorities and subsequent regulatory frameworks for a privatised water utility sector. However, current regulatory frameworks for investment may be favouring financial selection of strategic water resource solutions within, rather than, across current river catchment and commercial boundaries. Research into more dynamic regulatory, modelling and management control frameworks is required including development of more affordable and resilient quality and performance monitoring and adaptability to climate change. (See also Appendix 5 thematic reviews: "Resources",	There is some belief that current UK quality regulation, set to protect aquatic environments for infrequent adverse conditions leads to higher energy and chemical usage at wastewater plants than desired from sustainability and cost perspective. Should regulators help UK industry more in exporting our integrated river basin management regulatory and operational frameworks, which are highly regarded in China and other high growth regional economies?

	Evidence	References	Brief recommendations/key comments from reports	Reviewer's synthesis comments
			"Infrastructure", "Industry", "High impact events", "Sustainability and climate change", "Markets")	
5	**The issues of water security in developing countries needs to be addressed more rigorously, particularly in relation to MDGs**			
	Developing countries and external support agencies need to demonstrate greater political commitment to sanitation and drinking water, target resources and accelerate progress to meeting Millennium Development Goal targets	(1, 12, 14, 29, 71)	Progress towards sanitation goals in Developing Countries are significantly behind safe drinking water provision. Political and financial commitment at international and national level is vital. Affordable and deliverable solutions require education and capacity building at national and local scale. In developing countries the relationship between irrigation and food production is generally more important than compared to the UK. Effective decision-making is hampered by insufficient or inadequate hydrological, quality and health risk data. Developments are needed and opportunities exist in areas such as: cell-phone driven data collection, water resource database development, remote sensing and space observation. UK has strengths in communication technologies, satellites, modelling, databases, GIS. Need means for rapid, low cost detection of water-borne pathogens in the field, critical and much needed gap for Developing Countries. (See also Appendix 5 thematic reviews: "MDG", "Food", "High impact events")	Communication, capacity building and data collection are the big, strategic "must haves" to target and deliver safe water and sanitation, connecting and building upon more localised initiatives. Developments in irrigation are essential to food security. Modern bio-tech approaches, higher yield crops and technologies for conserving and safe re-use of water are needed. Should the UK focus international aid mainly on water and sanitation in Africa and is there a potential partnership with China to engage UK and international aid agencies and NGOs?
6	**Research & Commercial Opportunities from addressing water security**			
	The UK water	(2, 3, 4, 5,	Innovation is the source of increased productivity, choice and	The current Regulatory model for

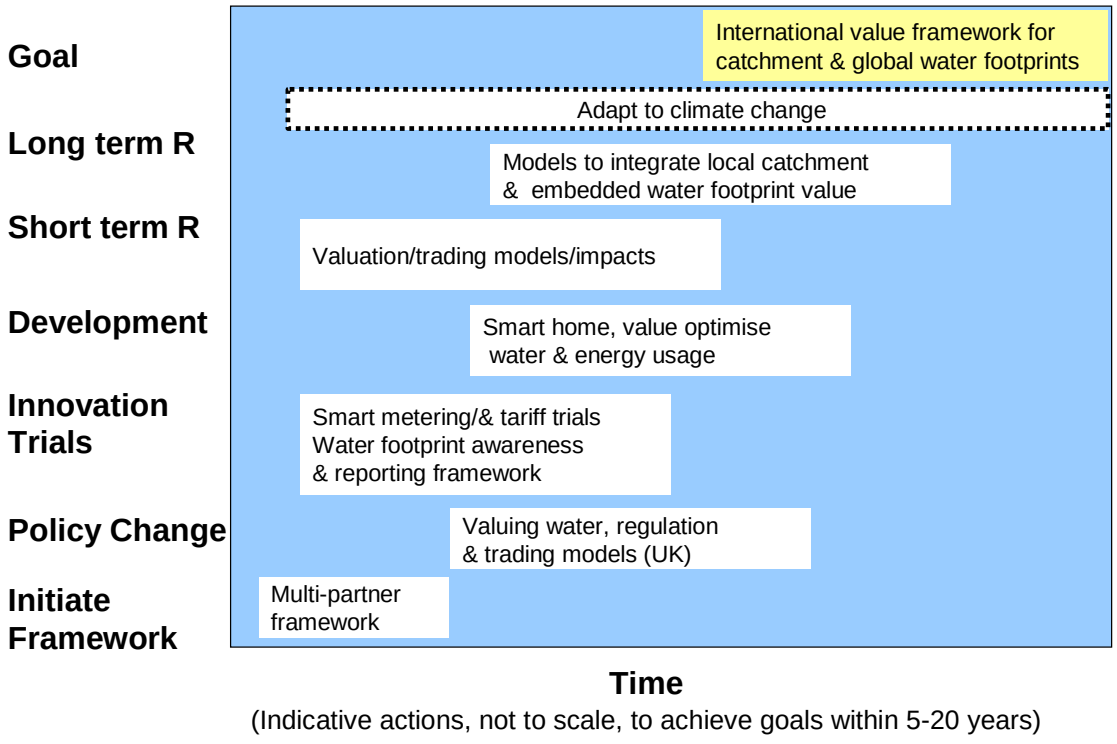
	Evidence	References	Brief recommendations/key comments from reports	Reviewer's synthesis comments
	industry averages approx. £4Bn capital and £4Bn operational expenditure per year, but the UK has fewer innovations in water per capita than Australia, Germany or USA, although the UK does attract patenting activity from abroad	6, 8, 9, 10, 33, 64)	value for customers OECD (Innovation Strategy: Getting a Head Start on Tomorrow) states *"there is a substantial body of evidence innovation is the dominant factor in national economic growth"* There is both the scope and the need for innovation in the UK water sector, including the need to develop new types of resources (eg re-use, desalination) and smart technologies and approaches to reduce demand and consumption Overseas water markets are estimated to be at least $500Bn / yr growing to $770 Bn / yr and can provide important opportunities for UK consultants, contractors and suppliers An Innovation Platform for Water could be established similar to TSB's Low Impact Building Innovation Platform (See also Appendix 5 thematic reviews: "Industry", "Market", "Infrastructure")	the UK water industry has not been directed to provide a strong basis for supporting research, development and innovation across the UK water sector and supply chain and has no remit to support growth into external markets The reports highlighted a number of disparate approaches to prioritising research direction to address water security - there is a need for a more holistic methodology. New technologies and approaches to the reuse of poor quality water resources (roof and road run-off water, wastewater, saline water) may be best directed to industrial and agricultural use where risks to human health can be minimised. Technology breakthroughs are often first applied to high value, niche and confined applications with lower risk to public health and the environment.

4 Analysis and Recommended Actions

In this section evidence and findings from Appendix 5 and Section 3 have been analysed and further synthesised with review team recommendations for actions.

4.1 Valuing water

Figure 3 Innovation activity map to achieve water security: Valuing water

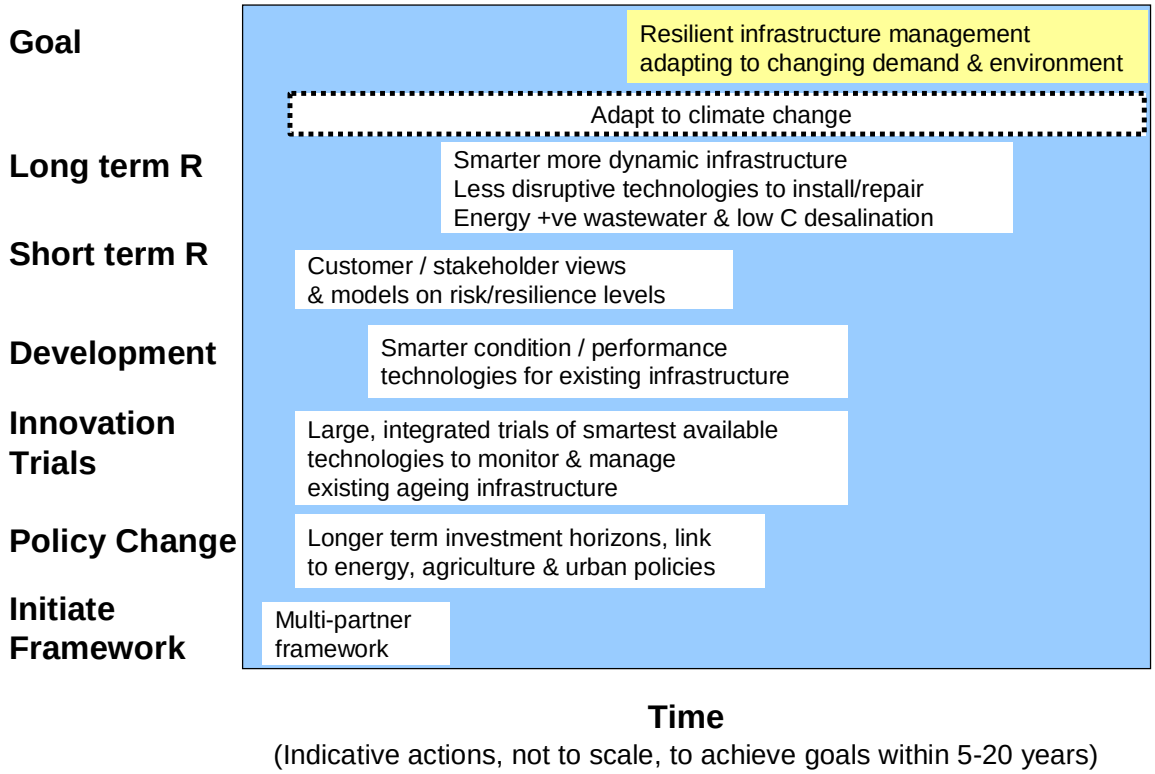


(Indicative actions, not to scale, to achieve goals within 5-20 years)

- Water is recognised as a 'fundamental human right'.
- Water is currently not valued correctly by stakeholders; this is a major problem in itself and contributes to misuse.
- Most UK domestic customers do not know how much water they use or their individual water footprint. Industry has started to report on water security but has limited knowledge of supply chain water footprint or security.
- To safeguard security, raw water in particular should be valued taking account of location, volume, availability, quality and needs. It is suggested that a valuation framework is developed, to cover the range from negative value (polluted water) through neutral (seawater) to a positive value of high quality natural freshwaters and methodologies to value virtual or embedded water.
- It is proposed that a multi-partner framework is established to provide leadership and direction of water valuation research and methodology development from raw water valuation and trading models through to customer behaviour, communication, usage, metering, tariff structure and water footprint.
- The suggested goal is to achieve a UK, and eventually internationally, agreed framework model for valuing and trading water, to correctly price future water services and to support decision making on adaptation to a changing environment and demand patterns.

4.2 Resilient infrastructure

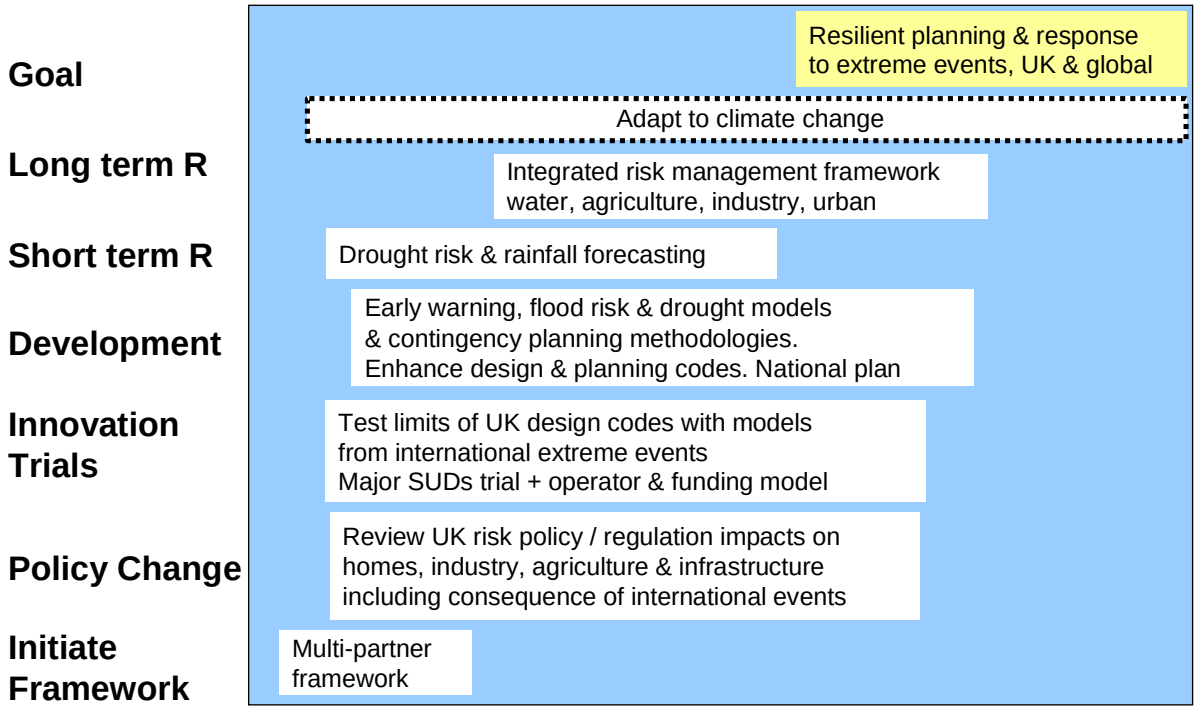
Figure 4 Innovation activity map to achieve water security: Resilient infrastructure



- There are clear risks in respect of UK water infrastructure, in terms of resilience and ability to adapt to changing demands and environment. Longer term investment horizons linked to policy on energy, agriculture and urban planning are required. Infrastructure planning, including community scale solutions, requires understanding of changing societal behaviours and service levels acceptable to customers.
- Innovation is needed to provide technology, modelling and "smarter assets" to improve accurate location, condition and performance assessment and deterioration rates of buried infrastructure. This should include understanding and managing multi-utility, traffic and natural environment interactions and provide smarter technologies to access, repair and install buried infrastructure with minimal urban disruption.
- There is a need for reduction in the carbon footprint of both constructing and operating water and wastewater infrastructure. Energy positive wastewater treatment and low carbon desalination should be longer-range research objectives.
- It is proposed that a multi-partner framework is established to provide leadership and direction of water infrastructure research, development and innovation.
- Researchers should recognise that improving knowledge and management of existing infrastructure will have far greater impact in the UK over the next 30 years than investment in completely new infrastructure. New infrastructure has a greater potential impact and market opportunity where first time urbanisation is growing rapidly e.g. China.

4.3 Hazard risk management

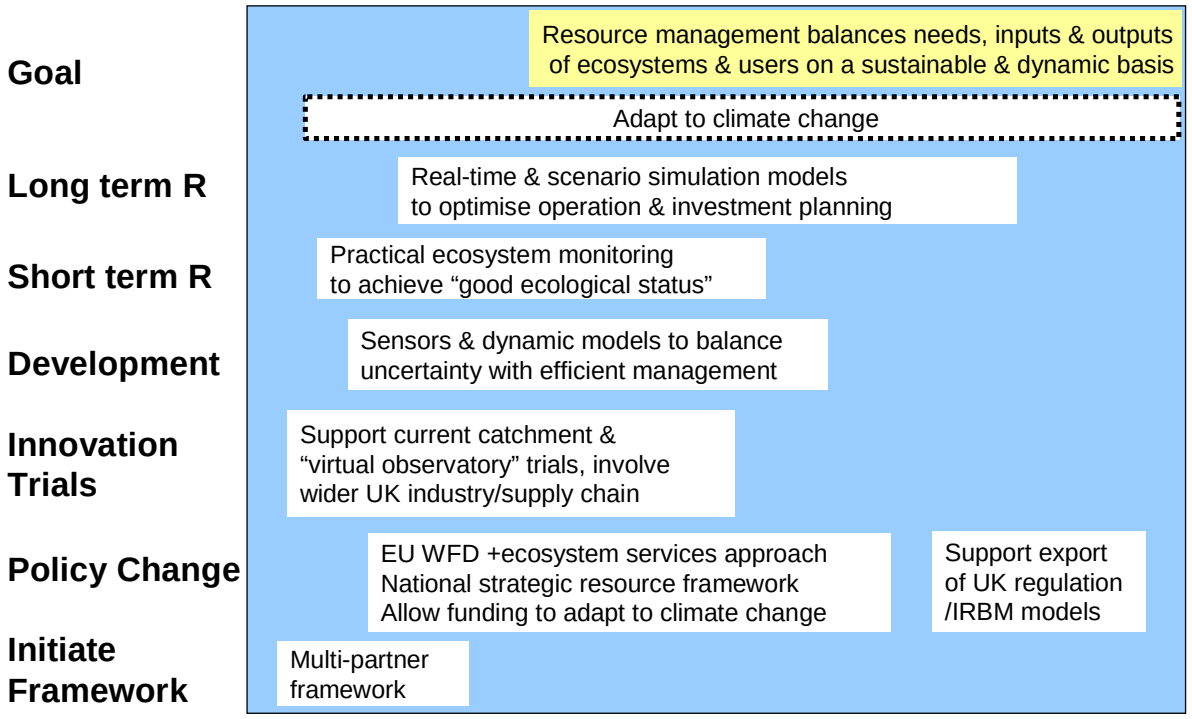
Figure 5 Innovation activity map to achieve water security: Hazard risk management



- Floods are seen as the most important natural hazard in UK and Europe in terms of life and economic loss. Flooding is not just a UK or European issue e.g. serious flooding or droughts in China could increase global competition for food or put at risk, key components of our industrial supply chain.
- Prolonged, large scale droughts are the second most important water related natural hazard in the UK and perhaps the greatest hazard to our international food supply chain. In the past 30 years, impact of droughts increased by 20%, affecting 11% of EU population, 17% of land area and cost impacts of circa 100 billion euros.
- Develop integrated land use planning and flood risk infrastructure, together with better predictive modelling capabilities and improved engineering and infrastructure options
- Location of large energy generation assets is inextricably linked to consideration of natural water hazards including, river or coastal flooding, droughts, risks of quality contamination and cooling water heat impact on natural water ecosystems.
- Affordable, innovative solutions are required to address the potentially huge investment challenges of providing flood protection and sustainable drainage.
- It is proposed that a multi-partner framework is established to provide leadership and direction of high impact water hazard risk management research and development of affordable adaptive infrastructure investment and response planning to UK and international extreme events.

4.4 Integrated resource management

Figure 6 Innovation activity map to achieve water security: Integrated resource management

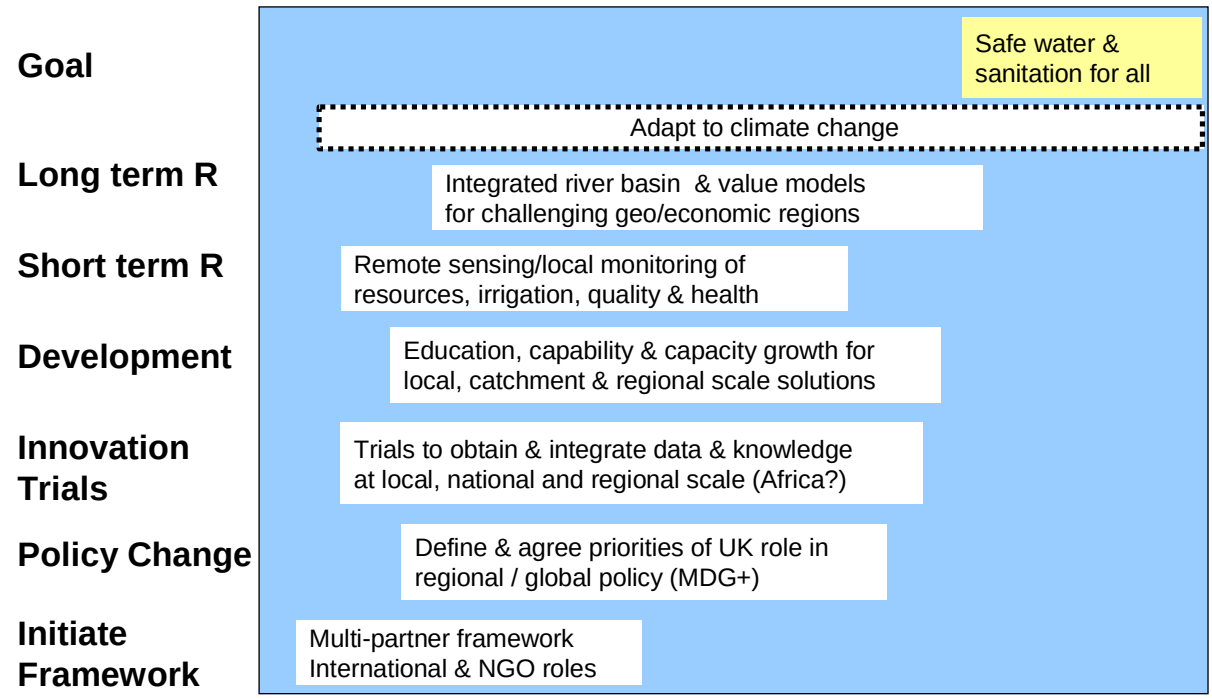


(Indicative actions, not to scale, to achieve goals within 5-20 years)

- Integrated river basin or water resource management frameworks incorporating needs, inputs and outputs from the natural ecosystem, agriculture, industry and urban domestic customer are recognised as increasingly essential.
- The UK has recognised leadership in integrated river basin management, building upon the 1974 Water Act which created multi-functional river basin water authorities and regulatory frameworks. Should regulators help UK industry more in exporting our integrated river basin management regulatory and operational frameworks, which are highly regarded in China and other high growth economies?
- Current regulatory frameworks for investment may favour financial selection of strategic water resource solutions within, rather than, across current river catchment and commercial boundaries.
- Research is required into more dynamic regulatory, modelling and management control frameworks, including development of more affordable and resilient quality and performance monitoring.
- Current EU Water Framework Directives do not fully incorporate or recognise the benefit of ecosystem services.
- It is proposed that a multi-partner framework is established to provide leadership and direction of integrated water resource management including adaptation to climate change.

4.5 Safe water & sanitation for all

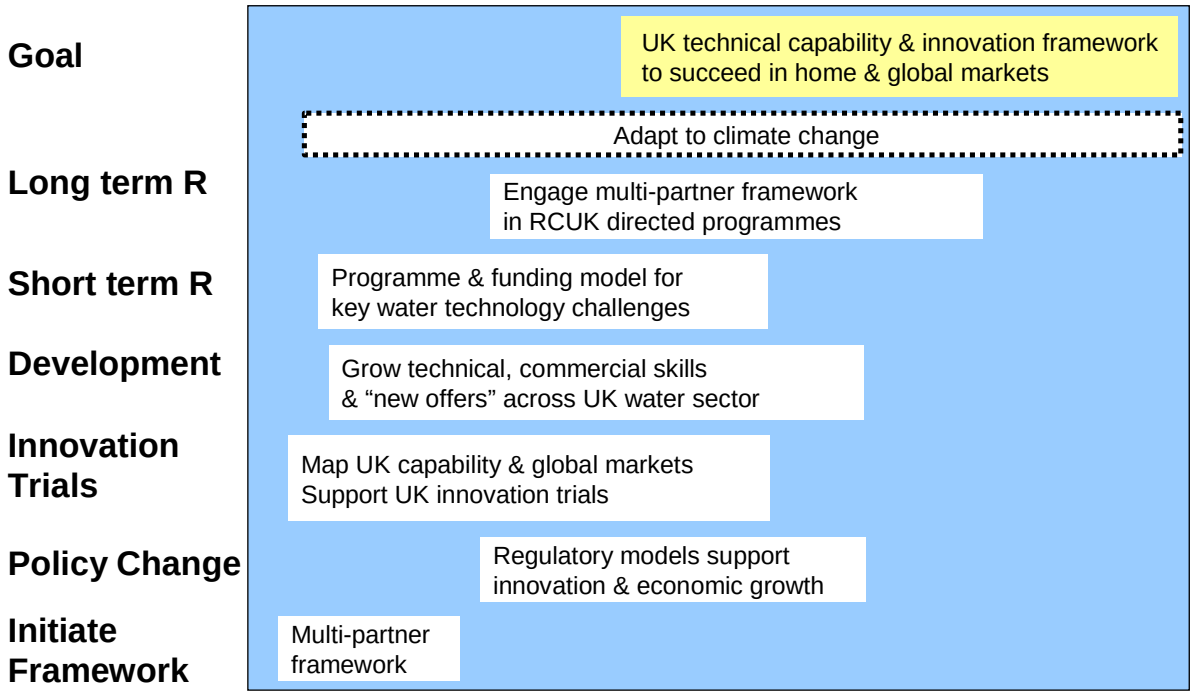
Figure 7 Innovation activity map to achieve water security: Safe water & sanitation for all



- Developing countries and external support agencies need to demonstrate greater political commitment to sanitation and drinking water, target resources and accelerate progress to meeting Millennium Development Goal targets.
- Progress towards sanitation goals in Developing Countries are significantly behind safe drinking water provision. Political and financial commitment at international and national level is vital.
- Affordable and deliverable solutions require education and capacity building at national and local scale.
- In developing countries the relationship between irrigation and food production is generally more important than compared to the UK.
- Effective decision-making is hampered by insufficient or inadequate hydrological, quality and health risk data. Developments are needed and UK opportunities exist in areas utilising cell-phone driven data collection, water resource database development, remote-sensing and space observation.
- It is proposed that a multi-partner framework is established, including international NGOs, to provide leadership and direction of research and innovation supporting achievement of the Millennium Development goals for safe water and sanitation for all.

4.6 Growing UK water economy

Figure 8 Innovation activity map to achieve water security: Growing UK water economy



- There is a need for innovation in the UK for development of smarter infrastructure, metering technologies, energy positive wastewater treatment and smart approaches to reduce flooding and water demand. Demand for new water resources in global markets requires new water reuse and low carbon desalination solutions.
- The UK water industry averages £4Bn capital and £4Bn operational expenditure per year, but the UK has fewer innovations in water per capita than Australia, Germany or USA. Overseas water markets are estimated to be at least $500bn per annum providing growth opportunities for UK consultants, contractors and suppliers
- The current Regulatory model for the UK water industry is not directed to provide a strong basis for supporting research, development and innovation across the UK water sector and supply chain and has no remit to support growth into external markets
- Investment in reported research in the UK water utility sector has fallen from 0.7 to 0.3 % of turnover in the past decade. It is suggested that investment in research and innovation across the whole UK water sector should be 1-2% of potential capital and operating expenditure, more typical in the UK engineering and production sector. This would imply a UK wide innovation investment need of between £200m and £500m over a 5-7 year period, to make a significant impact.
- It is proposed that a multi-partner framework is established, to provide leadership and direction of research and innovation across the full spectrum of UK water technology and services, including explicit support for UK economic growth in global markets.

5 Discussion, Conclusions and Recommendations

There is a clear need to establish a framework for joint innovation action across the water sector. Leadership is an issue. It is suggested that time-limited action frameworks are established to precisely define objectives and delivery programmes and to oversee funding mechanisms in the priority areas of need identified in this report. Membership may include: water utilities, regulators, academia, NGOs, consultants, contractors, and supply chains**.**

Investment in reported research in the UK water utility sector has fallen from £45m to £18m or 0.7 to 0.3 % of turnover in the past decade. It is suggested that investment in research and innovation across the whole UK water sector should be 1-2% of potential capital and operating expenditure, more typical in the UK engineering and production sector. This would imply a UK wide, innovation investment need of between £200m and £500m over a 5-7 year period, to make a significant impact by 2030 on delivery of improved water security in a rapidly changing environment. This should also support increased export opportunity, particularly in the service and infrastructure technology management sector increasing UK economic growth in the current £500bn, and forecast £770bn, global water market.

There is an increasing concern in water security and need for innovative and affordable solutions, evidenced by the volume of recent published reports reviewed in this study. The issues are complex and cover a wide range of political, social, environmental and technical challenges. Water security in the UK is significantly impacted by our imported, global water footprint and is inextricably linked to food and energy security and long term urban planning. A UK framework providing leadership and direction for delivering research and innovation in the 6 priority sectors identified in this report is recommended to increase UK water security and economic growth opportunities in the global water market.

.

6 References

1 *Africa's Water Quality - A Chemical Science Perspective* (March 2010) The Royal Society of Chemistry

2 *Independent Review of Competition and Innovation in Water Markets: Final Report* (April 2009) Prof. Martin Cave, Defra

3 *Charting Our Water Future- Economic frameworks to inform decision-making* (2009) The 2030 Water Resources Group 2030WaterResourcesGroup@mackinsey.com)

4 *Global Water Security - an engineering perspective* (April 2010) The Royal Academy of Engineers

5 *Improving innovation in water industry: 21st century challenges and opportunities* (March 2009) Council for Science and Technology

6 *Infrastructure, Engineering and Climate Change Adaptation –ensuring services in an uncertain future* (February 2011) Royal Academy of Engineering on behalf of *Engineering the Future*

7 *Population: One Planet, Too Many People?* (January 2011) Institution of Mechanical Engineers

8 *A Road Map of Strategic R&D Needs to 2030* (April-July 2007) UKWIR (Report Ref: 07/RG/10/3)

9 *UK Water Innovation – Which Way Forward in Europe?* (2009-2010) UKWIR (Report Ref: 10/PM/02/1

10 *Research and Innovation in the UK Water Industry* (2010-2011) UKWIR (11/Rg/10/5)

11 *Next Generation Science for Planet Earth, 2007-2012* Nerc Strategy 2007 – 2012 (2007), Natural Environment Research Council

12 *UN-Water Global Annual Assessment of Sanitation and Drinking (GLAAS) 2010 - Water- Targeting resources for better results* (2010) World Health Organization

13 *Valuation of water as a separate resource - RICS information paper* (January 2011 First Edition) Royal Institution of Chartered Surveyors

14 *The United Nations World Water Development Report 3: Water in Changing World* (2009) World Water Assessment Programme UNESCO

15 *29th Report- Demographic Change and the Environment* (February 2011) Royal Commission on Environmental Pollution, Chairman: Sir John Lawton www.official-documents.gov.uk Presented to Parliament by Command of Her Majesty

16 *U.S. Water Policy: Water Security is Human Security* (April 2011) Draft US Geological Survey (USGS) report to Congress (April 2011)

17 *Ensuring Water for All- Scoping Study Final Report* (March 2010) Environment Agency

18 *Future Water -The Government's Water Strategy for England* (2009), DEFRA

19 *Looking after Water in Africa – ESA'a TIGER Initiative meets the challenges posed*

at the Johannesburg Summit (February 2004) ESA bulletin 117

20 *NERC Directed Programme Themes, Sustainable Use of Natural Resources, Natural Hazards and Climate (2009-14),* Theme Action Plans, 1–3 (2009-11), Changing Water Cycle, Droughts, Floods, Virtual (water) Observatory. www.nerc.ac.uk

21 *Perspectives on Water and Climate Change Adaptation - Climate change and the water industry– practical responses and actions (2009), CPWC* Co-operative Programme on Water and Climate, IWA and World Water Council, www.waterandclimate.org

22 *Securing Our Water Future* (2010) Australian Government Department of Environment, Water, Heritage and the Arts

23 *Status Report on Integrated Water Resources Management and Water Efficiency Plans* (May 2008) UN-Water (prepared for the 16th session of the Commission on Sustainable Development – May 2008

24 *Summary of Responses to the Water White Paper Online Survey* (April 2011) Defra

25 *Walker Review of Charging for Household Water and Sewerage Services- Final Report* (December 2009) Anna Walker CB

26 *Water for All Grand Challenge; Large Scale Solutions to Water Scarcity*, EPSRC (2010). UKWIR contributed input challenges, Sandpit held 2011, output awaited

27 *Water in China (*February 2010*)* Responsible Research, Environmental, Social Governance in Asian Region, www.responsibleresearch.com Lucy Carmody (Editor)

28 *Strategic Research Agenda* (2010) WssTP

29 *Summary and Policy Implications, Vision 2030: The resilience of water supply and sanitation in the face of climate change.* (2009) World Health Organisation & Dfid - Anon

30 *Valuing Water: How upstream markets could deliver for consumers and the environment* (5th November 2010) An Ofwat focus Report

31 *Resilience Thinking: Sustaining Ecosystems and People in a Changing World* (2006) Brian Walker PhD (Author), David Salt **(**Author)

32 *Meeting Future Water Challenges- a blueprint for policy action* (June 2010) Water UK

33 *The Future of the UK Water Sector* (2008) All Parliamentary Water Group

34 *World Water: Resources, Usage & the Roll of Manmade Reservoirs* (2010), Foundation for Water Research, ROCK Review of Current Knowledge

35 *Emerging Issues in Water in Infectious Disease* (2003) World Health Organisation

36 Householders Guide to Private water Supplies (May 2010) Foundation for Water Research

37 *Crisis, What Crisis?- How to Stop Water Becoming the Next Global Catastrophe* (25th August 2008) New Scientist (article)

38 *Engaging with the Water Sector for Public Health benefits: waterborne pathogens*

and diseases in developed countries (10 May 2010) in Directing Water Science Towards Health Objectives, Bull World Health Organ 2010, Jonathan W. Bridge et al

39 *Water Resources in England & Wales – current state & future pressures* (December 2008) Environment Agency

40 *Water in Food Security Assessment & Drought Early Warning: experience from sub-Saharan Africa with special focus on Ethiopia* (March 2011) RiPPLE Working Paper 21, Josephine Tucker & Leulsegend Yirgu

41 *Sustainable Water Management Inside & Around Large Urban Areas* (September 2009) WssTP

42 *An Economic Analysis of Virtual Water in Agriculture* (2010) Organisation for Economic Co-operation and Development

43 *Multilingual Summaries- Sustainable Management of Water Resources in Agriculture* (2010) Organisation for Economic Co-operation and Development

44 *Integrated Agriculture- water saving options in irrigation, looking for efficient technologies, irrigation management and adapted cropping practices* (September 2010) WssTP

45 *Climate Change & the Water Sector- Impacts and Research Needs* (December 2010) WssTP

46 *Strategies for the safe management of drinking water for human consumption* (14th April 2011) World Health Organisation

47 *Future Water – the Government's Water Strategy for England (unpublished – powerpoint presentation)* Dr Cheryl Case – Programme Manager DEFRA

48 *How well is the UK prepared for climate change? (*September 2010) Adaptation Sub-Committee

49 *Water Scarcity & Droughts* – 2012 Policy Review – Building Blocks – Non-Paper (date unknown) European Commission, Directorate General – Environment

50 *Adapting to Climate Change: A review for the environmental audit committee* (July 2009) National Audit Office

51 *A Strong Britain in an Age of Uncertainty: The National Security Strategy* (October 2010) Presented to Parliament by the Prime Minister

52 *National Infrastructure Plan 2010* –(October 2010*)* HM Treasury

53 *Strategy for National Infrastructure* –(March 2010) HM Treasury

54 *Climate Change - Good Practice from the 2009 price review (*2009) Ofwat

55 *Whatever the Weather – managing the risks from a changing climate* (Sept 2010) CBI

56 *River Basin Planning Guidance (August* 2006) Defra

57 *Water today, water tomorrow – Ofwat and sustainability* (March 2009) Ofwat

58 *UK Water Initiative – water: a priority issue for the UK in a global context (Summary)- (Date?)* LWEC (Living with Environmental Change)

59 *The Future of Research on Climate Change Impacts on Water – A workshop*

focusing on adaptation strategies and information needs (2011) UKWIR / WRF

60 *The Government's Response to Sir Michael Pitt's Review of the Summer 2007 Floods* Progress Report (December 2009) Defra

61 *Climate Change Adaptation in the Water Sector* (2009) Co-operative Programme on water and climate. (ed: Ludwig, Kabat, van Schial & van der Valk)

62 *Sustainable Management of Water Resources in Agriculture* (March 2010) Organisation for Economic Co-operation & Development

63 *Review of the use of irrigation water in UK agriculture and the potential risks to food safety* (November 2007) Report to the Food Standards Agency

64 *CDP Water Disclosure 2010 Global Report* (2010) Carbon Disclosure Project by ERM

65 *Blueprint for Water:10 Steps for Sustainable Water by 2015* (November 2006) Blueprint for Water

66 *Force feeding the Countryside – the impacts of nutrients on birds and other biodiversity. Evidence Review* (May 2006) RSPB

67 *Rich Countries, Poor Water (Date?)* World Wildlife Fund (WWF)

68 *Challenges of Water Scarcity- A Business for Case Financial Institutions (Date?)* UNEP Finance Initiative

69 *Eco-Systems and Human Wellbeing: Wetlands and Water* (???) Millennium Eco-Systems Assessment.

70 *Sick Water? A Central Role of Waste Water Management in Sustainable Development* (2010) UN Habitat

71 *Achieving the Millennium Goals in Africa* (June 2008) Recommendations of the MDG Africa Steering Group

72 *UK National Ecosystem Assessment – Understanding Nature's Value to Society* (May 2011) Living With Environmental Change

73 *Innovation Priorities for the Water Sector* (May 2011) Water Sector Innovation Leadership Group OFWAT

74 *Engineering to Live within Planetary Boundaries: Civil Engineering Research Needs*. (4th April 2011) Institution of Civil Engineers

75 *Climate Resilient Infrastructure: Preparing for a Climate Change*. (May 2011) DEFRA

76 *UKCP2009,UK Climate Projections, Briefing Report* (2009) Defra

77 *Department of Economic and Social affairs/Population Division Report - World Population to 2300* (2004) United Nations

78 *2000, Water Framework Directive* (2000/60/E) European Commission

79 Office of National Statistics – web site ref http://www.statistics.gov.uk/CCI/nugget.asp?ID=1352)

80 *State of World Population 2007, Unleashing the potential of Urban Growth* (2007) UNFPA

81 *Water Scarcity and Droughts, Second Interim Report* (2007) European

Commission

82 *Foresight, Future Flooding– Summary Report* (2004) Office of Science and Technology

83 *Flood and Costal Erosion Risk Management (FCERM) Research Strategy* (2011) Defra & The Environment Agency

84 *CAMERAS – A Coordinated Agenda for Marine, Environment and Rural Affairs Science 2011-2016* (2011) The Scottish Government

85 A BLUEPRINT To Safeguard Europe's Water Resources – Discussion Document

86 *The 2010 R&D Scoreboard* (2010) BIS Department for Business Innovation & Skills

87 *Drinking Water 2010 Private Water Supplies in England* (due July 2011)

88 *Small Scale Supplies in the Pan-European Region* (2010) OECD/WHO Regional Office for Europe

89 Project improves river quality http://www.southwestwater.co.uk/index.cfm?articleid=7398).

90 Time for a change (2010) British Water article at http://www.britishwater.co.uk/News/Detail.aspx?uid=1fa41051-0fb5-4f23-bfeb-0006ba945f0b

Appendix 1 Client Brief

This project will carry out a high level overview and synthesis of recommendations from key policy and research reports (excluding academic journals) relevant to the UK's potential contribution to UK and global water security.

The scope of the mapping study will focus evidence and recommendations addressing the following priority themes:

- Changing societal and business behaviours in relation to efficient water use, access and supply and minimise water footprints
- Adapting agricultural systems to competing pressures to help ensure sustainable food supply
- Achieving water security for industry to underpin their business health
- Ensuring a suitable equitable and affordable supply and treatment of water for diverse communities
- Assessing the impact of water markets on society, business and the environment
- Increasing resilience of our water management systems, buildings and critical infrastructure
- Developing integrated water resource management approaches that account for the impact of a changing environment on the water cycle

Recommendations and evidence catalogued under each of these themes should also be critiqued against overarching and longer-term aspirations of:

- Ensuring water sustainability in a changing climate with growing population and competing land pressures
- Achieving optimal water use, supply and waste water treatment in response to these pressures without increasing energy consumption and whilst providing protection for the water environment
- Responding to changes in frequency and duration of extreme and high impact events (including climatic, natural and human induced events
- Maintaining and developing ecosystem functions and biodiversity for a sustainable supply of water resources.

Appendix 2 Reviewers and their Expertise

Reviewer	Qualified Expertise	Professional Experience	Current Affiliation(s)
Dr Jonathan Chenoweth	Planning & Environmental Scientist	Academic research & training, natural resources management	U. Surrey-SWIRL, Centre for Environmental Studies (CES)
Jeff Farrow	Chartered Civil Engineer	Engineering, design, contracting, innovation, water utility,	Independent Consultant, Advisory Board SWIRL
Linda Godfrey	MBA – innovation & knowledge management	Water utility, customer centre & R&D knowledge management	Independent Consultant- customer services, knowledge management
Dr Martin Griffiths	Hydrobiologist	Water utility, Env. Agency, Defra, TSB. Catchment science strategy	Pillon Ltd, Consultant, Visiting Prof. Kings College, London
Kirstie Hatcher	MA Media & Fine Arts	Academic network / project management, market communication	U. Surrey-SWIRL, Research & Enterprise Support
Prof Louise Heathwaite	Environmental Hydrologist	Academic research catchment land & water quality interactions.	U. Lancaster, Director, Sustainable Water Management & NERC
Sian Hills	Environmental Scientist	Water utility, pollution control, R&D, UK/Intn'l, water reuse expert	Independent consultant-sustainable water services
Prof Alan Jenkins	Hydrologist-Chemist	Academic research, international adviser, hydrology & water quality	NERC Centre for Ecology & Hydrology, Director of Water
Prof. Soon-Thiam Khu	Civil Engineer	Academic research & international consulting urban systems	U. Surrey-SWIRL, Chair of Urban Water Engineering Systems
Prof Stephen Morse	Biology & Crop Scientist	Academic research & training, agriculture & sustainable development	U. Surrey-SWIRL, Chair Systems Analysis for Sustainability, CES
Dr Steve Pedley	Microbiologist - Virologist	Academic research & training, UK & developing world public health	U. Surrey-SWIRL & Robens, Dir. WHO Collaborating Centre WQ&H
Tony Rachwal	Chemist - Environmental & Process	Water utility R&D director -Europe Industry Business Fellow,U.Surrey	Tony Rachwal & Associates, consultant, SWIRL & NERC SISB
Keith Robson	Electronic Engineer	MD electronics company, academic business incubation,	U. Surrey, Director of Research & Enterprise, Board Member ISIC
Prof Chris Rogers	Civil & Geotechnical Engineer	Academic research, buried pipes detection & trenchless technology	U. Birmingham, Head of Infrastructure Resilience

Appendix 3 Master Resource List and Priorities for Review Process

Overall Priority	No	Resource Title	Hard Copy	Electronic Copy	Theme	Theme 2
Primary	1	*Africa's Water Quality - A Chemical Science Perspective* (March 2010) The Royal Society of Chemistry	YES	YES	d)	
Primary	2	*Independent Review of Competition and Innovation in Water Markets: Final Report* (April 2009) Prof. Martin Cave, Defra	YES	YES	e)	
Primary	3	*Charting Our Water Future- Economic frameworks to inform decision-making* (2009) The 2030 Water Resources Group 2030WaterResourcesGroup@mackinsey.com)	YES	YES	a), b), c), f)	i) ii)
Primary	4	*Global Water Security - an engineering perspective* (April 2010) The Royal Academy of Engineers	YES	YES	c) f)	
Primary	5	*Improving innovation in water industry: 21st century challenges and opportunities* (March 2009) Council for Science and Technology	YES	YES	e) f)	
Primary	6	*Infrastructure, Engineering and Climate Change Adaptation –ensuring services in an uncertain future* (February 2011) Royal Academy of Engineering on behalf of *Engineering the Future*	YES	YES	a) f)	i)
2ndary	7	*Population: One Planet, Too Many People?* (January 2011) Institution of Mechanical Engineers	YES	YES	a) g)	i)
Primary	8	*A Road Map of Strategic R&D Needs to 2030* (April-July 2007) UKWIR (Report Ref: 07/RG/10/3)	YES	NO	f)	
Primary	9	*UK Water Innovation – Which Way Forward in Europe?* (2009-2010) UKWIR (Report Ref: 10/PM/02/1	YES	NO	e), f)	
Primary	10	*Research and Innovation in the UK Water Industry* (2010-2011) UKWIR (11/Rg/10/5)	YES	NO	e), f), g)	

Overall Priority	No	Resource Title	Hard Copy	Electronic Copy	Theme	Theme 2
2ndary	11	*Next Generation Science for Planet Earth, 2007-2012* Nerc Strategy 2007 – 2012 (2007), Natural Environment Research Council	YES	YES	a)	i) ii) vi)
Primary	12	*UN-Water Global Annual Assessment of Sanitation and Drinking (GLAAS) 2010 -Water- Targeting resources for better results* (2010) World Health Organization	YES	YES	d)	
2ndary	13	*Valuation of water as a separate resource - RICS information paper* (January 2011 First Edition) Royal Institution of Chartered Surveyors	YES	NO	a)?	
Primary	14	*The United Nations World Water Development Report 3: Water in Changing World* (2009) World Water Assessment Programme UNESCO	YES	YES	d) a)	
Primary	15	*29th Report- Demographic Change and the Environment* (February 2011) Royal Commission on Environmental Pollution, Chairman: Sir John Lawton www.official-documents.gov.uk Presented to Parliament by Command of Her Majesty	YES	YES	g)	
2ndary	16	*U.S. Water Policy: Water Security is Human Security* (April 2011) Draft US Geological Survey (USGS) report to Congress (April 2011)	PART	NO	a)?	
Primary	17	*Ensuring Water for All- Scoping Study Final Report* (March 2010) Environment Agency	YES	YES	a), b), c), e), g)	i), ii), iv)
Primary	18	*Future Water -The Government's Water Strategy for England (2009), DEFRA*	YES	YES	a), b), c), e), g)	ii)
2ndary	19	*Looking after Water in Africa – ESA'a TIGER Initiative meets the challenges posed at the Johannesburg Summit (February 2004) ESA bulletin 117*	YES	NO	d)	
2ndary	20	*NERC Directed Programme Themes, Sustainable Use of Natural Resources,*	NO	NO	a)	iii)

Overall Priority	No	Resource Title	Hard Copy	Electronic Copy	Theme	Theme 2
(Prime for iii)		*Natural Hazards and Climate* (2009-14), Theme Action Plans, 1–3 (2009-11), Changing Water Cycle, Droughts, Floods, Virtual (water) Observatory. www.nerc.ac.uk				
Primary	21	*Perspectives on Water and Climate Change Adaptation - Climate change and the water industry– practical responses and actions (2009), CPWC* Co-operative Programme on Water and Climate, IWA and World Water Council, www.waterandclimate.org	YES	YES	a)	i)
2ndary	22	*Securing Our Water Future* (2010) Australian Government Department of Environment, Water, Heritage and the Arts	YES	YES	b), g)	
Primary	23	*Status Report on Integrated Water Resources Management and Water Efficiency Plans* (May 2008) UN-Water (prepared for the 16th session of the Commission on Sustainable Development – May 2008	YES	YES	a), g)	
2ndary	24	*Summary of Responses to the Water White Paper Online Survey* (April 2011) Defra	YES	YES	e), g)	
Primary	25	*Walker Review of Charging for Household Water and Sewerage Services-Final Report* (December 2009) Anna Walker CB	YES	YES	e), g)	
2ndary	26	Water for All Grand Challenge; Large Scale Solutions to Water Scarcity, EPSRC (2010). UKWIR contributed input challenges, Sandpit held 2011, output awaited	NO	NO	f)	

Overall Priority	No	Resource Title	Hard Copy	Electronic Copy	Theme	Theme 2
2ndary	27	*Water in China (*February 2010*)* Responsible Research, Environmental, Social Governance in Asian Region, www.responsibleresearch.com Lucy Carmody (Editor)	YES	YES	a), b), c), d)	
2ndary	28	*Strategic Research Agenda* (2010) WssTP	YES	YES	f)	
Primary	29	*Summary and Policy Implications, Vision 2030: The resilience of water supply and sanitation in the face of climate change.* (2009) World Health Organisation & Dfid Anon	YES	YES	d)	i)
Primary	30	*Valuing Water: How upstream markets could deliver for consumers and the environment* (5th November 2010) An Ofwat focus Report	YES	YES	e), g)	
2ndary	31	*Resilience Thinking: Sustaining Ecosystems and People in a Changing World* (2006) Brian Walker PhD (Author), David Salt (Author)	YES	NO		iv)
Primary	32	*Meeting Future Water Challenges- a blueprint for policy action* (June 2010) Water UK	YES	YES	e), g)	
Primary	33	*The Future of the UK Water Sector* (2008) All Parliamentary Water Group	YES	YES	e)	
2ndary	34	*World Water: Resources, Usage & the Roll of Manmade Reservoirs* (2010), Foundation for Water Research, ROCK Review of Current Knowledge	YES	YES	b), c)	
2ndary	35	*Emerging Issues in Water in Infectious Disease* (2003) World Health Organisation	YES	YES	d)	
2ndary	36	Householders Guide to Private water Supplies (May 2010) Foundation for Water Research	YES	YES	g)	
2ndary	37	*Crisis, What Crisis?- How to Stop Water Becoming the Next Global Catastrophe* (25th August 2008) New Scientist (article)	NO	NO	b)?	
2ndary	38	*Engaging with the Water Sector for Public Health benefits: waterborne pathogens and diseases in developed countries* (10 May 2010) in Directing Water Science Towards Health Objectives, Bull World Health Organ 2010,	YES	YES	a) g)	

Overall Priority	No	Resource Title	Hard Copy	Electronic Copy	Theme	Theme 2
		Jonathan W. Bridge et al				
Primary	39	*Water Resources in England & Wales – current state & future pressures* (December 2008) Environment Agency	YES	YES	b), e)?	
2ndary	40	*Water in Food Security Assessment & Drought Early Warning: experience from sub-Saharan Africa with special focus on Ethiopia* (March 2011) RiPPLE Working Paper 21, Josephine Tucker & Leulsegend Yirgu	YES	YES	b) d)	
Primary	41	*Sustainable Water Management Inside & Around Large Urban Areas* (September 2009) WssTP	YES	YES	f) (Topic2) g) (Topic4)	
Primary	42	*An Economic Analysis of Virtual Water in Agriculture* (2010) Organisation for Economic Co-operation and Development	YES	YES	b)	
2ndary	43	*Multilingual Summaries- Sustainable Management of Water Resources in Agriculture* (2010) Organisation for Economic Co-operation and Development	YES	YES	b)	
Primary	44	*Integrated Agriculture- water saving options in irrigation, looking for efficient technologies, irrigation management and adapted cropping practices* (September 2010) WssTP	YES	YES	b)	
Primary	45	*Climate Change & the Water Sector- Impacts and Research Needs* (December 2010) WssTP	YES	YES	a)	
Primary	46	*Strategies for the safe management of drinking water for human consumption* (14th April 2011) World Health Organisation	YES	YES	d)	
Primary	47	*Future Water – the Government's Water Strategy for England (unpublished – powerpoint presentation)* Dr Cheryl Case – Programme Manager DEFRA	YES	YES		

Overall Priority	No	Resource Title	Hard Copy	Electronic Copy	Theme	Theme 2
Primary	48	*How well is the UK prepared for climate change? (*September 2010) Adaptation Sub-Committee	YES	YES	a)	i)
2ndary	49	Water Scarcity & Droughts – 2012 Policy Review – Building Blocks – Non-Paper (date unknown) European Commission, Directorate General - Environment	YES	YES	a), b) g)	i), iii)
Primary	50	*Adapting to Climate Change: A review for the environmental audit committee* (July 2009) National Audit Office	NO	YES	a)	i)
Primary	51	*A Strong Britain in an Age of Uncertainty: The National Security Strategy* (October 2010) Presented to Parliament by the Prime Minister	YES	YES	f)	
Primary	52	*National Infrastructure Plan 2010* –(October 2010*)* HM Treasury	YES	YES	f)	
Primary	53	*Strategy for National Infrastructure* –(March 2010) HM Treasury	YES	YES	f)	
2ndary	54	*Climate Change - Good Practice from the 2009 price review (*2009) Ofwat	YES	YES	a), e)	
2ndary	55	*Whatever the Weather – managing the risks from a changing climate* (Sept 2010) CBI	YES	YES	b), c)	
2ndary	56	*River Basin Planning Guidance (August* 2006) Defra	YES	NO	a)	
2ndary	57	*Water today, water tomorrow – Ofwat and sustainability* (March 2009) Ofwat	YES	YES	e), g)	i)
Primary	58	*UK Water Initiative – water: a priority issue for the UK in a global context (Summary)-date unknown* LWEC (Living with Environmental Change)	YES	YES	Back-ground to all	
2ndary	59	*The Future of Research on Climate Change Impacts on Water – A workshop focusing on adaptation strategies and information needs* (2011) UKWIR / WRF	NO	NO	a)	i)
2ndary Primary	60	*The Government's Response to Sir Michael Pitt's Review of the Summer 2007 Floods* Progress Report (December 2009) Defra	YES	NO	e), f)	iii)

Overall Priority	No	Resource Title	Hard Copy	Electronic Copy	Theme	Theme 2
for iii)						
2ndary	61	*Climate Change Adaptation in the Water Sector* (2009) Co-operative Programme on water and climate. (ed: Ludwig, Kabat, van Schial & van der Valk)	YES	NO		
2ndary	62	*Sustainable Management of Water Resources in Agriculture* (March 2010) Organisation for Economic Co-operation & Development	YES	NO		
2ndary	63	*Review of the use of irrigation water in UK agriculture and the potential risks to food safety* (November 2007) Report to the Food Standards Agency	NO	YES		
Primary	64	*CDP Water Disclosure 2010 Global Report* (2010) Carbon Disclosure Project by ERM	YES	YES	c)	
2ndary	65	*Blueprint for Water:10 Steps for Sustainable Water by 2015* (November 2006) Blueprint for Water	YES	YES		
2ndary	66	*Force feeding the Countryside – the impacts of nutrients on birds and other biodiversity. Evidence Review* (May 2006) RSPB	YES	YES	iv)	
2ndary	67	*Rich Countries, Poor Water* (?) World Wildlife Fund (WWF)	YES	NO	iv)	
2ndary	68	*Challenges of Water Scarcity- A Business for Case Financial Institutions* (???) UNEP Finance Initiative	YES	NO	c) industry and e) market	
2ndary	69	*Eco-Systems and Human Wellbeing: Wetlands and Water* (???) Millennium Eco-Systems Assessment.	YES	NO	iv)	

Overall Priority	No	Resource Title	Hard Copy	Electronic Copy	Theme	Theme 2
2ndary	70	*Sick Water? A Central Role of Waste Water Management in Sustainable Development* (2010) UN Habitat	YES	NO	iv)	
Primary	71	*Achieving the Millennium Goals in Africa* (June 2008) Recommendations of the MDG Africa Steering Group	YES	YES		
Primary	72	*UK National Ecosystem Assessment – Understanding Nature's Value to Society* (May 2011) Living With Environmental Change	YES	YES		
Primary	73	*Innovation Priorities for the Water Sector* (May 2011) Water Sector Innovation Leadership Group OFWAT	YES	YES		
Primary	74	*Engineering to Live within Planetary Boundaries: Civil Engineering Research Needs*. (4th April 2011) Institution of Civil Engineers		YES	f)	
Primary	75	*Climate Resilient Infrastructure: Preparing for a Climate Change*. (May 2011) DEFRA		YES	f)	
Primary	76	*UKCP2009,UK Climate Projections, Briefing Report* (2009) Defra		YES		
2ndary	77	*Department of Economic and Social affairs/Population Division Report - World Population to 2300* (2004) United Nations		YES		
Primary	78	*2000, Water Framework Directive* (2000/60/E) European Commission		YES		
2ndary	79	Office of National Statistics – web site ref http://www.statistics.gov.uk/CCI/nugget.asp?ID=1352)		YES		
2ndary	80	*State of World Population 2007, Unleashing the potential of Urban Growth* (2007) UNFPA		YES		
Primary	81	Water Scarcity and Droughts, Second Interim Report (2007) European Commission		YES		
Primary	82	*Foresight, Future Flooding– Summary Report* (2004) Office of Science and Technology		YES		

Overall Priority	No	Resource Title	Hard Copy	Electronic Copy	Theme	Theme 2
Primary	83	*Flood and Costal Erosion Risk Management (FCERM) Research Strategy* (2011) Defra & The Environment Agency				
Primary	84	*CAMERAS – A Coordinated Agenda for Marine, Environment and Rural Affairs Science 2011-2016* (2011) The Scottish Government				
Primary	85	A BLUEPRINT To Safeguard Europe's Water Resources – Discussion Document				
2ndary	86	*The 2010 R&D Scoreboard* (2010) BIS Department for Business Innovation & Skills				
2ndary	87	*Drinking Water 2010 Private Water Supplies in England* (due July 2011)				
2ndary	88	*Small Scale Supplies in the Pan-European Region* (2010) OECD/WHO Regional Office for Europe				
2ndary	89	Project improves river quality http://www.southwestwater.co.uk/index.cfm?articleid=7398).				
2ndary	90	Time for a change (2010) British Water article at http://www.britishwater.co.uk/News/Detail.aspx?uid=1fa41051-0fb5-4f23-bfeb-0006ba945f0b				

Appendix 4 Example Summary of Report

Title of report: Valuing Water (30)
Reviewer name:

1. Summary of the report's key conclusions relevant to assigned topic:

- There is currently no value for water.
- The industry needs to adapt to increasing challenges (climate, population growth, consumer expectations, economic uncertainty, affordability issues and costs of implementing EU legislation), in order to deliver sustainable water.
- Tools need to encourage companies and customers to use water more efficiently, either by trading water between areas or by moving the water demand between areas.
- Trading in water resources could help secure water and sewerage services for the future.
- The report considers a 'hypothetical model' for upstream regulated water markets as a first step towards more effective markets.
- The hypothetical model includes 3 ideas from the Cave review (creation of upstream water supply licences; new access pricing rules that enable entry on a fair basis; making abstraction trading easier.
- The model also explores "implementing water trading arrangements that encourage or require companies to by and/or sell a small proportion of their water" and "create functionally independent system operators".
- Unbundling the combined water supply licence would allow new entrants to sell and buy water without having to have their own customers to retail water to, and upstream new entrants without its own assets could buy access to water treatment works, storage reservoirs and transport networks, on a fair and non-discriminatory basis.

2. Strategic issues, risks or opportunities identified:

Risks

- Changes to water regulation, business separation and water trading will incur costs. Customers need to be protected against unwarranted price changes
- Medium term changes could create 'regional system operators', and in SE England this would require the merger of several companies' business units.

Opportunities

- Environmental benefits (prevention of over abstraction), encourage companies to develop new sources where sources are plentiful.
- More security of supply for customers

Benefits

- Water trading should provide customers with lower water bills, increased choice and increased security of supply

3. **Quality of evidence presented, exemplar case studies referenced:**

   - Much mention of the Cave review.
   - Water trading successfully takes place in: US – Colorado, the Big Thomson project transfers water across the Rocky Mountains, and in Australia the Murray-Darling Basin includes 4 states and 1/7th of Australia

4. **Key identified enablers / barriers to practical application:**

   Barriers

   - Will need UK Coalition Government and Welsh Assembly Government to decide if they will take recommendations forward
   - Potential barrier to water trading – current price review mechanisms are only kept for 5 years.
   - Potential barriers to setting up functionally separate system operators: costs, loss of coordination benefits between network asset owners and the system operator. A change in regulation would be needed to ensure that the system operator was incentivised to maximise coordination benefits and minimise costs.

5. **Key identified implementation, trials of known technology or short term innovation recommendations:**

   - Water trading in US and Australia (see 3 above)
   - Short term innovation recommendations introduce water trading and functional separation of system operators

6. **Key identified longer term research needs:**

   - Medium to longer term changes could create 'regional system operators', although in south east England this would require the merger of several companies' business units.

Appendix 5 Summary and Synthesis of All Themes

A 5.1 "Customer":

Evidence & recommendations for changing societal and business behaviours in relation to efficient water use, access & supply and minimise water footprints

Evidence from reports
In the 14 reports reviewed for this theme, there is agreement that there is an impending water crisis and a general consensus that ***behaviours need to be changed*** in relation to water efficiency, access & supply and water footprints (all)

Most reports were from accredited organisations with adequate references, but on detailed analysis it transpired that key source information on customer views was not included.

There was ***much cross-referencing of reports*** eg Cave, Walker, OFWAT.

The UN recognise water as a ***"fundamental human right***" (7) and this generally reflects societies attitude and behaviour towards it.

It was recognised that globally overall ***water footprints would increase*** as countries developed eg changing diets and industry needs (7). However most of the reports, which were also Government/Regulator outputs, focused ***on the UK customer*** and UK situation (17,18,24,25,30,32,33,57)

Additionally most reports looked at customer ***per capita demand*** (ie 148 litres per day (15)) ***rather than overall water footprint***. Only one report (18) referred to the Waterwise water footprint figure of 3,400 litres per day, representing water also embedded in food and other manufactured products.

The UK population will reach 71 million by 2031 and is likely to be largest in EU by 2050; and many countries, including UK have ***exported*** their ***demand for water*** by importing water-intensive goods from elsewhere. In the future the UK may not be able to export as much demand for water as climate change impacts increase (57)

Many reports highlighted that the ***value*** of water is not fully understood by customers and stakeholders which encourages profligate behaviour. (30, 32, 25).

There is ***very high level*** of reported UK (England and Wales) ***customer satisfaction*** with water (95%) and a high level of satisfaction with wastewater (94%). Provided the basics are reliable and transparent pricing, customers are reported as willing to support more sustainable and environmental actions (32)

"Willingness to pay has fallen, but expectations of service have grown" Bad debt issues reflect this and the issue of inability to disconnect. "Won't pay" customer behaviour reflects a certain customer segment's attitude to water. (32)

There was ***little evidence*** that demonstrated ***measured examples*** of changes in behaviour that resulted in reductions in demand and footprint, but there were many recommendations for future actions that were postulated to achieve this aim.

Recommendations from reports

Implement better ways to "**value"** water which should reduce usage. Regulatory recommendations include ***water trading, unbundling, abstraction licence changes*** (30,p3, 32,p3, 25,p9) but do customers want a liberalised market ? (32)

Regulatory/ legislative type ***recommendations*** targeted at ***reducing usage, encouraging efficiency and changing behaviours*** (including business behaviours eg water companies) included *flexible regulation, longer investment periods, abstraction licensing, new tariff structures, water trading, appliance labelling, phasing-out of inefficient products, housing regulations, customer incentives to minimise surface water run-off*

Water saving messages & advice to customers should be stronger & more consistent & water efficiency ***initiatives promoted more*** (linked to energy saving), incentivised & organised (33,18)

Implement **metering** as it is fairer than RV and may encourage efficient behaviour but the vulnerable must be protected. Explore the potential for **smart meters/innovative tariffs** (25)

Consistent agreement across stakeholders that ***collaborative actions are needed*** to improve future water security for all customer sectors and this included actions related to this theme (all)

Models and scenarios for future demographics and ***water footprint*** (2030 – 2050) are needed. Models to investigate competition scenarios & all stakeholders acceptability are also recommended (30)

Putting the ***customer first*** is foremost in most reports (e.g. 25, 32) as more engagement should result in better understanding of water issues and hence hopefully more sustainable behaviour.

Strengthening/changing CC Water is recommended (18,p85, 32,p8)

Research into **costs and benefits of water efficient measures** recommended (25)

EU research recommendations to feed into FP7 from WssTP (41) related to this theme include: SoS tools, improving **customer perception** & involvement to facilitate efficient water use, better **understanding demand** from different sectors, **advanced metering, footprint indicators to facilitate public participation, desalination** (energy), **reuse** (black & grey), **rainwater harvesting** & **managed aquifer recharge.**(41)

Research into the **scale of environmental migration** resulting from climate change (7,)

Additional comments from reviewers

Water : Energy Nexus, where water and energy are intimately linked – energy is required to make use of water (2% of UK electricity usage) and water is needed to make use of energy (approx. 45% of UK water abstraction). In a UK domestic home most of the energy consumption is to heat water and to return warm wastewater to sewers multiplying the carbon

footprint of this type of domestic water use by a factor of 5-8. The opportunity and benefits for integrated smart energy and water metering with intelligent appliances and customer information systems is a recommended research area.

Although putting the customer first is foremost in most reports, (e.g. 25, 32) but how is **real customer** consultation **achieved**, rather than self-interested individuals response?

Encouraging that general consensus/cross referencing to Cave, Walker etc but is there danger of **"groupthink",** resulting in lack of innovation?.

Agreement that changes to regulation & governance required but are proposals **far-reaching enough & enough impetus** - who takes the lead?

In the UK the current system works i.e. we get water delivered and sewage taken away, and bills less than for mobile phones for many, so are **drivers for significant reform**, such as a water supply crisis, lacking?

Has the **public health** imperative been adequately considered – eg what are DWI views on water trading and 3rd party access to assets?

Ensuring behavioural change/can **customer** behaviour be modified? (ref Defra report 2008 Framework for Pro-Environmental Behaviour & review team view)

The **effectiveness** of **water efficient strategies**/schemes (via demo.trials) (10,p33)

A 5.2 "Food"

Adapting agricultural systems to competing pressures to help ensure sustainable food supply

Reviewer 1	Reviewer 2	Reviewer 3
3, 17, 18, 22, 42	27, 44	39, 40 (2 parts), 43
1. Summary of the theme's key conclusions and recommendations		
- **concepts such as "virtual water" and "water footprints" are useful for provoking discussion but not useful tools for determining policy.** -while there may be a growing global agricultural water supply-demand gap there is no single water crisis but many specific localised problems; food production presents the key global water challenge. -while agricultural water use in the UK is very low, regionally and seasonally it can be significant.	- classic issues of water availability vs water demand illustrated in China but on a scale that outstrips that seen in developed countries - water pricing in China remains a major constrain on innovation and on water security now and into the future. - to some extent, pricing remains an issue in Europe w.r.t. innovation drivers and water conservation	- in the UK some catchments are over licensed or over-abstracted, and we need to restore a sustainable abstraction regime. East and South East of England are especially vulnerable - lack of access to an adequate quantity and quality of water for hygiene is a leading cause of water-related disease, which in turn causes malnutrition as it reduces the body's absorption of nutrients. - lack of access to adequate water for livestock watering, irrigation and small-scale productive purposes reduces the opportunities for household food production and/or income generation. - lack of adequate nearby water sources results in a long time being spent in daily water collection, principally by women and girls, which reduces the time available for work or education, and can also negatively affect health. - current economic and market conditions create new challenges and new opportunities for policy reform
Overall conclusions: - issues of demand outstripping supply (China, UK) but no single water crisis and instead there are specific localised problems – the scale of which is greater in China - food production presents the key global water challenge but is also important vis-à-vis hygiene and water-related disease – the latter have less focus than water for crops - in the UK some catchments are over-abstracted and while agricultural water use is low it can be significant on regional (e.g. East and South East of England)/seasonal scales – these are the areas of greatest water stress. Such 'geographical (distributional) water challenges' appear to exist worldwide - pricing is an issue in Europe and can create new challenges/opportunities for policy reform		

Reviewer 1	Reviewer 2	Reviewer 3
2. Strategic issues, risks or opportunities identified		
-Without substantial efficiency gains, global water demands may grow by 50% by 2030 at the same time as water resources availability uncertainty grows due to climate change. -In the UK climate is likely to change to wetter winters and drier summers.	- appropriate environmental regulation and control in critical developing countries such as China is at an early stage so environmental degradation on a large scale might be expected to continue into the future. - Immediate impacts on food security may not be clear but the concomitant reduction in water security via water quality degradation will be the hidden threat	- increasing demand for water as population increases - drier and warmer environment expected in the UK as a result of climate change will result in higher demands by households and farmers - multifaceted impacts of water on food security - links between water shortage and food security have rarely been analysed **- new methods of linking water shortage and food security issues are required.** **- better links are needed between those responsible for service delivery and those working in disaster risk management and emergency response.** **- better sharing of information and skills, with the ultimate goal of joint programming between responses to drought and food insecurity**
Overall conclusions - increasing demand for water as population increases and at the same time the uncertainty of the availability of water grows due to climate change - in the UK the climate is likely to change towards wetter winters and drier/warmer summers and this may increase seasonal demand - multifaceted impacts on food security hence impacts in any one place may not be clear. Indeed the links between water shortage and food security have rarely been analysed at appropriate scales; most analysis is simply limited to irrigated agriculture - new methods for linking assessments of water shortage and food security are required - better sharing of information and skills across those charged with addressing drought and food security		
3. Quality of evidence presented, exemplar case studies referenced		
-global agricultural data and water use data were used in some reports; case studies were also used, such as India, China, Brazil and South Africa.	- claimed to be poor for China and not available at appropriate scales for Europe e.g. need for 'soil wettability' data for irrigation efficiencies.	-global data often used. -some case studies (Ethiopia)

Reviewer 1	Reviewer 2	Reviewer 3
Overall conclusions - global data sets employed - some case studies - quality of data in China is poor		
4. Enablers or barriers to practical application		
-**lack of information**, fragmented groups of users, and financial constraints all present challenges. -some issues can be managed by stakeholders working in partnership together.	- global water companies are acquiring increasing share of national water supply capacity (now 8% in China): opportunities for imposing higher standards of water use driven by internationally agreed protocols.	- need for water metering in the UK - **lack of application of some analytical tools** - lack of joined up approaches that link responses to drought and food insecurity - economic crisis of 2008
Overall conclusions - lack of information - lack of application of some analytical tools - need for more joined up approaches/partnerships - financial constraints (especially the economic crisis of 2008) - global water companies obtaining increasing share of national water supplies in China but this also provides opportunities for imposing higher standards		
5. Recommendations for implementation of solutions, trials of known technology or short term innovation		
-improved water productivity. -implementation of the Water Framework Directive may contribute to the development of a sustainable agricultural sector. -there is a need to share water between economic and environmental uses.		- water metering in the UK - new assessment/analytical tools such as the Water for Economy for Livelihoods (WELS) approach and – of course – remote sensing. - establish a more joined up approach to link responses to drought and food insecurity - negative impacts of high food prices on world hunger and poverty levels.
Overall conclusions - improved water productivity (making the most of available water) - implementation of Water Framework Directive (EU scale) - more metering is required in the UK - further develop analytical tools (Water for Economy for Livelihoods and remote sensing) - more joined up approach to link responses to drought and food security		
6. Recommendations for longer term research where vital knowledge is limited and no known or practical solutions are currently available		
	- **linking climate-based predictions of water scarcity/security with local scale land use and soils data:**	- often not specified in terms of new research as such - emphasis is more often on policy and institution factors

Reviewer 1	Reviewer 2	Reviewer 3
	the meeting point is catchment-scale science. Climate needs to downscale and soils needs to upscale for the dialogue to occur!	(such as encouraging better linkages)
Overall conclusions - linking climate-based predictions of water scarcity/security with local land use and soils data: this is a major downscaling/up-scaling issue - encouraging better linkages between institutions		

A 5.3 "Industry"

Achieving water security for industry to underpin their business health

Summary (3, 4, 6 primary data from 64**)**
The CDP Water Disclosure 2010 – Global Report (64) builds on the Carbon Disclosure Project (CDP) used for carbon reporting since 2003. The project is supported by 137 institutional investors, representing $16 trillion in assets. For the first time in 2010, 302 of the FTSE 500 global companies were asked to complete a questionnaire regarding their water strategies, management plans, risks, opportunities and on their water use in the context of local scarcity or abundance. A strong 50% response rate from 150 companies was reported as indicative of the importance placed on water by global corporations, of which 89% have developed specific water policies and 60% have set water related performance targets. UK FTSE 100 companies represented 10% of the respondents including BP, Glaxo and National Grid.

Conclusions were:-

- **Major companies have a good overall awareness of water risks and water usage within their own operations, but much less knowledge of their supply chains' water footprint.**
- **Water is a current, not a future, corporate issue, with more than half of the physical, regulatory or 'other' water related risks being classified as current or near term (1-5 years).**

Strategic issues, risks or opportunities identified

- The key water related risks were identified as:-
  - - flooding of company or supply chain premises.
  - -water related interruption of their energy supplies (grid or power plant)
  - -impact of regional and seasonal water stress on abstraction
  - -reputational risk to corporate brand from stakeholder perception that they are responsible for pollution and excessive water footprint
- Global corporations are identifying a wide range of water related opportunities:
  - Water management practices to reduce industry operating costs (mining, paper)
  - Increased urbanisation and population growth expanding the market for water treatment chemicals (particularly in Asia)
  - Growing demand for infrastructure, both in new urban areas and to adapt the existing infrastructure to climate change.

Cost of raw or tap water was not reported as a significant issue or risk. However the survey did not ask this question directly and reference was made to needing *"competitively priced sources of water"*.

Quality of evidence presented, exemplar case studies referenced:
A well managed survey. Good response from over 150 major global corporations using a methodology developed and applied by the Carbon Disclosure Project since 2003. Clear segmentation of industry sectors, clear evidence of responses and exemplar case studies, activities and quotations provided:- *"our goal is to reduce our Group freshwater use per tonne of product by 6% by 2013 from our 2008 baseline"*, Rio Tinto.

Key identified enablers / barriers to practical application:
The survey did not identify any major barriers to practical application of water-related risk surveys. However they are currently voluntary, with a wide variation in response rates between different industry sectors and geographies. *Perhaps only good corporate citizen companies respond? (Reviewers question).*

Key identified implementation, trials of known technology or short term innovation recommendations:
There is a clear need for improvement and focussed attention on supply chains water footprint.

Businesses are increasingly realising reporting on local water usage and discharge volumes is insufficient to assess risk and sustainable operation.

Processes of geographically and water context related to 'water footprinting' is practised by some but could be more consistently defined and practiced across international supply chain.

The survey indicates that global corporations could provide valuable input to planning global improvements of integrated river basin management.

"*IBM's technologies and solutions will enable business, governments and others to better understand, anticipate, and address the potential physical impacts of water resource limitations and the challenges brought by climate change",* IBM.

Key identified longer term research needs:
Predicting and adapting to climate change and cost effective, sustainable technologies for securing new water resources (reuse, desalination) were identified as future areas.

A 5.4 "MDG"

Ensuring a suitable equitable and affordable supply and treatment of water for diverse communities

Draws upon the following documents: 1; 12; 14; 29; 71

Summary of the theme's key conclusions and recommendations

- Scientists working within Africa have the knowledge, expertise and potential to help formulate and implement sustainable water strategies. (1)
- Integrated decision-making should be strengthened to tackle the pressures on water resources arising from numerous interconnected sources. (14)
- Inadequate hydrological and hydro-geological data is a major barrier to effective water resource management in developing countries. (1, 14, 29, 71)
- Data analysis and dissemination technologies for water resource management are inadequate. (1,14,71)
- Technology transfer between developed and developing countries needs to be improved. Remote sensing technologies should be employed to fill the data gaps. (14)
- Increasing Africa's capacity for water quality analysis is imperative in order to support monitoring and management activities. (1, 14)
- Improving water quality is a vital requirement for better public health, productivity and economic prosperity.(1)
- Food production accounts for a large proportion of total water use. (1, 71)
- Investment is needed in water conservation and reuse technologies for irrigation (14, 71).
- Governments must be responsible and accountable for providing sustainable water strategies and a framework to provide clean drinking water, sanitation services, and food. (1,14)
- Developing countries and external support agencies need to demonstrate greater political commitment to sanitation and drinking-water, given their central role in human and economic development (12, 14, 71)
- External support agencies and developing countries must consider how to better target resources to accelerate progress towards meeting the sanitation and drinking water MDG target. (12, 14,71)
- Climate change is likely to intensify the current problems with water resource management, and drinking-water supply and sanitation. (14, 29)
- Systems to increase the resilience of water supply and sanitation facilities are required. (29)

Conclusion: Hence the issues raised in the reports are mostly to do with capacity building, communications, management, data collection and analysis how this would impact on reaching the MDG targets through more effective water resource management.

Strategic issues, risks or opportunities identified

- A quarter of all people in Africa are experiencing water stress and this is largely a problem of distribution. (1, 14)
- Water scarcity is emerging as a major development challenge in some places. (1, 29)

- Climate change will increase the pressure on water resources, and will intensify the challenges already present to meet the MDGs (29)
- Hydrological and hydrogeological data are incomplete across Africa, and many other developing countries. This is the most significant hurdle to effective water resources management. (14, 71)
- Strengthening capacity for water resources monitoring and management is essential. Dissemination of technology to developing countries must be improved. (14, 71)
- Strengthening cross-sectoral communication and the use of integrated decision making will significantly improve water management. (14, 71)
- The application of water conservation and reuse technologies in agriculture could reduce the pressure on water resources and improve crop yields. (1, 71)
- Improvements in sanitation and drinking-water could reduce the number of children who die each year by 2.2 million. (12)
- Hence huge savings in health-care costs and gains in productive days can therefore be realized by improving access to safe water and basic sanitation. (12)
- But insufficient funds being allocated to meet the MDG target for sanitation and drinking-water. (12)

Conclusion: Somewhat oddly there does not seem to be any explanation as to why the allocation of resource is insufficient/poorly targeted given the stated importance of water!!!! Suggestion that the organisations involved with 'water' are more fragmented that in other sectors but is this really the only reason??

Quality of evidence presented, exemplar case studies referenced

- One report based upon conference presentations. (**1**)
- One report based upon the results of a three-part survey questionnaire and consultation process for data collection at country level. A total of 42 countries, 27 in sub-Saharan Africa, 10 in south or south-east Asia and 5 in other areas of the world, participated in the research. (12, 29)
- The other reports had been prepared for high level review groups and presented a synthesis of data from a broad range of sources. (14, 29, 71)

Enablers or barriers to practical application

- value of water is not being recognised (1, 14)
- insufficient resources being allocated to meet the MDG target for sanitation and drinking-water (12, 71)
- resources for sanitation and drinking-water are not necessarily well targeted to where the needs are greatest (12, 71)
- perceived higher level of fragmentation in the water sector compared to others (12)
- Improved data collection, management and data sharing (14, 29, 71)

Conclusion: Hence water sector is not being resourced enough for the MDG targets to be achieved.

Recommendations for implementation of solutions, trials of known technology or short term innovation

- A strong focus on developing and improving technologies to conserve and reuse water for agriculture is required. (1, 71)
- The impact of agriculture on the entire cycle of water use and water governance should be recognised. (1, 71)

- Developments in remote sensing, data management and data communication are essential to provide the basic information on water resources that is required to effectively manage those resources (14, 29,71).
- Improve the dissemination of technologies to developing countries. (14)
- Improve cross-sector communication to facilitate integrated decision-making. (14, 71)
- Increase communication, networking and capacity-building activities in water quality monitoring and assessment by providing, transporting and commissioning equipment in good condition to African research centres.(1, 14, 29 71)
- Develop centres of excellence in experimental techniques and strengthen the already successful 'centre of excellence' at Jomo Kenyatta University of Agriculture and Technology (1)
- Governments and universities should examine possible funding schemes that could be viable in Africa to facilitate creation of centres of excellence in the chemical and biological sciences. (1)
- Facilitate networking activities of African and non-African scientists in the area of water research and management. (1, 14)
- Networking among African scientists both within and outside Africa is vital if African R&D is to be engaged in the international arena **(1)**
- Every country must have a national water strategy and develop the policies to deliver it. (1)
- Need to promote sanitation and drinking water at political and aid levels. (1, 14, 29, 71)
- Need to establish clear roles and responsibilities for the different institutions involved in sanitation and drinking-water. (1, 12, 14)
- Better coordination between aid agencies and between them and government agencies so as to allow for a more targeted approach. (12, 14)
- Raise awareness of the potential impacts of climate change on water resources. (14, 29)
- Develop technologies and strategies to increase the resilience of water supply and sanitation facilities to climate change. (29)

Conclusion: Hence most of the recommendations are related to the need to improve capacity and promote networking /coordination so as to help highlight the importance of water and thus increase likelihood of meeting the MDG targets

Recommendations for longer term research where vital knowledge is limited and no known or practical solutions are currently available

- more linked to a need to enhance capacity and networking rather than research. (1, 12, 14)

A 5.5 "Market"

Assessing the impact of water markets on society, business and the environment

Summary of the report's key conclusions relevant to assigned topic:
There is currently no value for water [30]; Changes are needed to the regulatory regime to meet new challenges and Governments need to value water differently in the future [25]. In the UK water charges reflect the costs of supply and treatment, not the value of the scarce resource [30]

Ofwat's five year Periodic Review dominates [team view] and fixes approx £4 Bn capital, and £4 Bn operational per year, most spent in response to statutory minimum requirements of EU directives and maintaining and improving efficiency. This results in a very stop start process impacting adversely on the wider water sector and supply chain [90]

UK has fewer innovations in water per capita than Australia, Germany, Netherlands, Spain and USA, but UK does attract patenting activity from abroad [2]. [Team view] This means there is both the scope and the need for innovation in the UK water sector

Overseas water markets, estimated at $500 Bn, growing to $770 Bn are particularly important for the UK consultants, contractors and supply chain. [3] & [Team view]

Bad debt levels are higher than in the energy industry whilst average bills are much lower [25]. It is vital that the level and costs of bad debt are reduced and issues are addressed. [Team view] Not helped by the concept of water having no value, considered as a 'natural right' – when taken along with real public health issues, make it easy for people to avoid payment, and difficult to impose cutting off supplies for non-payment

Innovation is the source of increased productivity, choice and value for customers. OECD (Innovation Strategy: Getting a Head Start on Tomorrow – 2010) states *"…there is substantial body of evidence innovation is the dominant factor in national economic growth"* [10]

<u>Strategic issues, risks or opportunities identified:</u>
Trading in water resources could help secure water and sewerage services for the future [30] [2] [One reviewer agrees, the other fundamentally disagrees, stating, "There is nobody to trade with, the water companies have almost all the water."] Would need to ensure doesn't simply add new layers of cost and further barriers to innovation. Some focus on retail / commercial – but this could destroy any direct customer relationship with suppliers; cost per household is small (only 1/3rd of energy costs) – security and resource issues should be more important than retail savings

Recommendations for reform of licensing regime with market-like framework -greater incentives for innovation, but research other sectors, suggests that investment in research and development - adversely affected by the extension of competition [2]

Ofwat Team view: market competition / water company procurement practices - drive innovation – and push it down into the supply chain. [5] [Team view] Could result in short-termism and risk of capex savings at expense of good quality solutions

The Technology Strategy Board set up the Low Impact Building Innovation Platform (£47M) [10] [Team view] A similar Innovation Platform for Water is needed

Risk - if Ofwat *requires* companies to trade water there is a risk of customers seeing a decrease in the security of supply when water is short (i.e. companies selling water rather than meeting customer demand especially in times of low rainfall/drought).[25]

WssTP is the Water Supply & Sanitation Technology Platform and was initiated by the European Commission to promote the coordination and collaboration of Research and Technology Development in the water industry, aiming to link identified research with FP7 research calls "*Overcoming the (water) crisis with new R&D innovation that can give impulse to European industry* [41][Team view] UK is very under-represented, with missed opportunities for EU funding for R&D and 'openings' for UK business (eg Consultants, Contractors, Suppliers, Universities) into Europe

Quality of evidence presented, exemplar case studies referenced:
A number of Case Studies are considered and discussed eg SE Queensland Water Grid [2] successful water trading in the US Colorado and in Australia Murray-Darling Basin [25] [Team view] We should research, learn and understand how these could be successfully applied in UK and consider need for a "National Grid Co" for water – to manage all raw water resources and establish the right values on a national basis

Key identified enablers / barriers to practical application:
UK R&D spend in utilities sector was 0.29 % of turnover, is 40 % below worldwide avg, and considerably below UK avg all industries R&D spend of 1.7 % [2]; Ofgem Innovation Funding Incentive delivered 1/3 higher R&D intensity in its first year [2]

Ofwat's newly introduced SIM acts as barrier to innovation (eg risk that if a new innovation could result in customer complaints - major disincentive to company taking this risk) [10][Team view] Could introduce simple 'waiver' system

Key identified implementation, trials of known technology or short term innovation recommendations:
Ofwat should review incentives and Defra guidance for the next price review and continue with incentive changes already made and consider further changes for the next price review [10][Team view] Will ensure long delays, can UK afford to wait?
Tariff and smart metering trials, including synergies with energy sector [25]

Key identified longer term research needs:
Creation of an industry research and development body [2] [Team view] Recognise current gaps and need for new structure to lead and direct R,D & I across industry, with adequate sources of funding and ability to deliver research and innovation.

A 5.6 "Infrastructure"

Increasing resilience of our water management systems, buildings and critical infrastructure

Summary of the theme's key conclusions and recommendations

- The ***sector faces multiple challenges***, including climate change, growing population, increasing urbanisation, a vast and ageing infrastructure legacy, lack of investment, unhelpful regulatory regimes, high consumer expectations (high quality service, low price), skills shortages, carbon reduction targets, and threats of terrorism, cyber attack, international military crises and natural disasters [all]. This ***complex interaction of many pressures bumps up against what the planet can provide*** [74], yet we need to maintain the quality of the aquatic environment and bio-diversity [10].
- ***Resilience in one sector is dependent on resilience in another*** [6], there are ***complex interdependencies*** [5, 6, 74] and ***vulnerabilities need to be prioritised*** [6].
- We need to work in new ways to plan, design and maintain infrastructure both ***at a national and local scale*** [6], noting that a national water grid has been assessed as cost-ineffective and highly energy intensive [2], provide the wherewithal to ***build local infrastructure***, develop appropriate ***local arrangements that meet local needs and circumstances***, and ***enable innovative local infrastructure solutions*** [52], underpinned by ***integrated planning at multiple scales*** [74]. Private water supplies are recognised as a new challenge for innovative, affordable infrastructure in UK and Europe [87, 88]
- ***Buildings and their occupants need to be considered as part of the infrastructure system*** [6]. ***Behavioural change is likely to be needed to deliver the resilient solutions*** [6], and solutions should ***promote well-being and social inclusion*** [74].
- The ***capacity, quality and resilience of the UK's national infrastructure directly affect economic growth*** and ***competitiveness in the global economy*** [52, 53].

Strategic issues, risks or opportunities identified

- There is a need to ***manage expectations***. Water services are taken for granted [5], yet degradation and interruption of vital services is likely [6].
- There are ***trade-offs between efficiency and resilience***. Increased resilience comes at a cost, so failures might have to be accepted and openly discussed. Without certainty about revised service levels, the private sector will be reluctant to invest [6] ***Economic regulators should balance climate risk with efficiency and value for money*** [75]. Are ***existing incentive and penalty structures fit for purpose*** [75]?
- ***A multi-disciplinary, cross-sector approach with cross-profession collaboration*** is essential; ***commercial factors must not be allowed to dominate*** [6, 74, 75].
- Use of ***continuous monitoring*** to allow reactive and timely maintenance across all infrastructure can increase resilience. Sharing of the data for use in modelling infrastructure and scenario planning should be facilitated [6]. There is a need for ***smarter technologies*** (e.g. modern measurement and control systems) [5].
- The expected impacts of UK climate change will lead to conditions no more extreme than those currently experienced and dealt with elsewhere in the world. Technologies for adaptation exist in many countries, thus ***there are opportunities to learn from both technologies and regulatory frameworks overseas*** [6]. There is an opportunity to ***learn from, and share, adaptation experience on infrastructure from other countries***, in particular G20 countries [75].

Quality of evidence presented, exemplar case studies referenced

Much evidence is presented in the reports. None is worthy of repetition here.

Enablers or barriers to practical application

- Regulatory regime needs to ***incentivise Research and Innovation*** (R&I), which suffers from the current 5-year investment regimes and inadequate rewards for R&I [5], and this in turn militates against long-term thinking and planning [52].
- ***Sustainability of the water cycle*** is not properly dealt with by Government policy statements; this may be preventing changes in regulation and other areas that would promote innovation [10].
- ***Carbon reduction targets will have a significant impact on the infrastructure***, both in terms of technical requirements and user behaviour, and these should be modelled in tandem with the effects of climate change [6]. The water industry is a major user of energy (3% of UK energy usage) and has a large carbon footprint [5].
- There are serious skill shortages in the industry [5]. ***More engineers***, with the skills to deal with complex infrastructure systems, ***will be needed***. Developing engineering expertise will ***create marketable skills and solutions for export*** [6].
- Mechanisms to reward investment in R&D and innovation are needed [5], possibly via the regulatory regime. Fiscal measures, such as ***re-focussing R&D tax credits to science and engineering research that has a societal or environmental benefit***, rather than having to be primarily an advance in science, would help here [74].
- The Government's intention to ***establish a Green Investment Bank*** (GIB), which is ***mandated to invest in the low-carbon sector,*** is an enabler.

Recommendations for implementation of solutions, trials of known technology or short term innovation

There was nothing of particular note to report under this heading.

Recommendations for longer term research where vital knowledge is limited and no known or practical solutions are currently available

- ***Research into how local infrastructures might deliver greater resilience***, and mitigate national infrastructure issues, is needed [6]. ***Local arrangements to meet local needs and circumstances*** would facilitate ***innovative local infrastructure solutions***, ***to which the Big Society could contribute*** [52]. ***Optimum engineering solutions vary with scale*** and are dependent on other infrastructures, which might also operate at different scales; ***integration across multiple scales*** is needed [74].
- ***Probabilistic rather than absolute scenarios*** should be researched [6]. These should embrace ***the uncertainties related to climate and socio-economic change*** [74, 75], but should go wider to cover the myriad challenges listed above.
- ***Developing infrastructure that can serve multiple purposes*** [6] and ***multi-purpose operations*** (i.e. solutions with dual or multiple benefits) [74, 75] should be explored.
- There is a need to ***research further systems thinking*** to plan, design and maintain infrastructure [6, 52, 74]. Different thinking might be needed at different scales.
- There are multiple interdependencies between infrastructure systems and resilience in one sector is dependent on resilience in another. ***These interdependencies, hence vulnerabilities, need to be properly understood*** and ***solutions that remove the adverse effects of such interdependencies need to be researched***. [6, 52, 74]
- There is a need for ***greater understanding of (research into) behaviours,*** and the ***possibilities for engineering behavioural change*** while ***promoting well-being*** [6].
- A standard industry-led infrastructure ***carbon accounting model*** is needed [74].

A 5.7 "Resources"

Developing integrated water resource management approaches that account for the impact of a changing environment on the water cycle.

Climate Change – is a critical issue for water industry.
Looking forward 20 – 30 years we should expect 2-3 degrees increase in temperature which will bring: (from CP2009,76)

- Warmer wetter winters
- Hotter and drier summers – reduction of 22% rainfall in the South East
- Sea level rise

More severe weather events – increases in the amount of rain on the wettest days

Adaptation is a key challenge for the water industry – (Climate Change Adaptation subcommittee (48) – Infrastructure UK reports 6 -52 -53)

Population Growth and Migration also critical for UK and Internationally

UK Population is set to rise from 61million in 2008 to 71million in 2031 (*ONS Data* http://www.statistics.gov.uk/CCI/nugget.asp?ID=1352 (79). The situation is likely to be most acute in the South East of England where London's population is projected to grow from 7.6 million to 8.6 million by 2026, an increase of 15%

World population is projected to grow from 6.1 billion in 2000 to 8.9 billion in 2050, increasing by 47 per cent. (United Nations, 2004, Department of Economic and Social affairs/Population Division Report - World Population to 2300 (77)

In 2008, for the first time in history, more than half of the world's population will be living in towns and cities. By 2030 this number will swell to almost 5 billion, with urban growth concentrated in Africa and Asia. While mega-cities have captured much public attention, most of the new growth will occur in smaller towns and cities, which have fewer resources to respond to the magnitude of the change. (UN Population Fund (80)

IRBM/ Integrated River Basin Management

Acknowledged in most sources as the preferred approach – Water Framework Directive – (78) (Defra - Future Water (18) as key planning tool. Also use with Climate Change scenarios

Note the geographical issues relating to water and the need to manage in catchments. For example, need to account for downstream effects, also the difficulty and consequences of transferring water long distances between catchments.

Summary of the theme's key conclusions and recommendations –re IWRM and CC
Need to consider –

- Flooding – (Pitt Review (60), Foresight Future Flooding, (82) and subsequent reports)
    - Integrated drainage systems
    - SUDS – and wetland
    - Early Warning and flood risk methodologies
    - Novel engineering solutions
- Water Scarcity and Drought (EA Water Resources Strategy) (39) (EU) (81)
    - Improve infrastructure, water saving, leakage
    - Water reuse
    - Predictive modelling of river flows and resource estimations - close to industry
    - Drought Contingency planning
    - Economic impacts
- Water Quality Issues (Future Water), (18) (WFD) (78)
    - Efficiency of treatment – including energy optimisation and export
    - Land/Water interfaces – Eutrophication - Nitrates and Phosphates
    - Priority Substances Directive – new substances –oestrogenic substances (78) and subsequent Priority Substances reviews
    - Lack of dilution capacity

Other Key issues include

- Ageing and complex infrastructure – (Infrastructure UK 6 -52 -53)
- Cities and peri-urban infrastructure
- Costs of infrastructure replacement and adaptation to CC
- Links back to the value of water – Ecosystem Services –
- Geographical issues of water resources and availability between and across UK catchments

Strategic issues, risks or opportunities identified – re IWRM and CC

- Climate Prediction 2009 still the definitive work, but resolution spatially limited (60)
  - Need catchment level predictions – especially in water scarce catchments in SE
- Population Growth and urbanisation will put significant pressure on urban infrastructure – Opportunity (UK is good at retrofitting in cities and towns)
- Infrastructure is critical to UK economy and significant advantages to maintaining and improving this (Infrastructure UK) (6 -52 -53)
- Need to know more about extreme events in the water sector – Flooding and Drought (60)
- Assume current levels of water usage, but need to understand more about consumer behaviour
- Current infrastructure and engineering methods/solutions may not meet CC requirements – (Global Water Security (64)
- Need to increase resilience of water infrastructure
- Need integrated land and water solutions – eg wetlands, SUDS, land use planning (Defra Future Water) – (18)

Quality of evidence presented, exemplar case studies referenced – IWRM & CC

- Key works include

  Climate Predictions 2009 (76)
  Pitt Review and subsequent reports and actions (60)
  Cave Review (2)
  Future Water (18)
  Infrastructure UK (6 -52 -53)
  Climate Change Adaptation sub-group report (48)
  Charting our water future – McKinsey (3)
  UN reports (77,80)

Enablers or barriers to practical application - IWRM & CC

Enablers

Water Framework Directive
EU Floods and water scarcity reports
EU Innovation Strategy – key focus on water
Infrastructure UK
UK CC Act and Adaptation Sub-Committee
Water White Paper in autumn – if proper input and specification

Barriers

Climate Change - uncertainty over actual changes at catchment/water company level – but opportunities if got right
Costs of Adaptation and advance funding – complex water infrastructure
Lack of leadership across the sector to deal with integrated solutions.
Lack of water shareholder appetite for risk or change
Customer appreciation of real issues and risks
Board level leadership on these issues
Insufficient long term IWRM planning
Current OFWAT regulatory regime – relatively short term with very high levels of certainty used needed. Short term fixation with low prices and purist view on who pays (Walker Review)
No good view of value of water – cost of too much or too little water

Lack of innovation and commercialisation in monopoly water industry– (Cave Review)

Cross Research Council initiatives in infancy – improve close to business knowledge and climate for take up

No drivers for innovation and step change in water (eg Code 6 Homes in Building Sector) – water industry a victim of its own stepwise and risk averse coping strategy

Recommendations for implementation of solutions, trials of known technology or short term innovation – IWRM & CC

Need to develop land use planning and integrated flood risk infrastructure (Pitt+)

Need to develop water resource/water quality/flooding planning assumptions and methods to take into account climate change and adaptation scenarios

Develop further water valuation scenarios, especially for water scarce catchments and extreme events

Further development of real time control and management opportunities across infrastructure (egYorkshire Water - RtRiver-i)

Improve climate for SUDS, Wetland solutions, soft engineering and sacrificial land for flood and water resource.

Improve and develop urban water planning tools

Improve and develop water reuse opportunities – mico and macro level

Develop risk tools with Insurance industry

Recommendations for longer term research where vital knowledge is limited and no known or practical solutions are currently available – IWRM & CC

Climate change scenarios on water at catchment scale

Impacts on Air, Land and Water and optimised solutions

Costs and opportunities of adaptation

Social interactions and possibility of step changes in behaviour

City infrastructure optimisation and control options

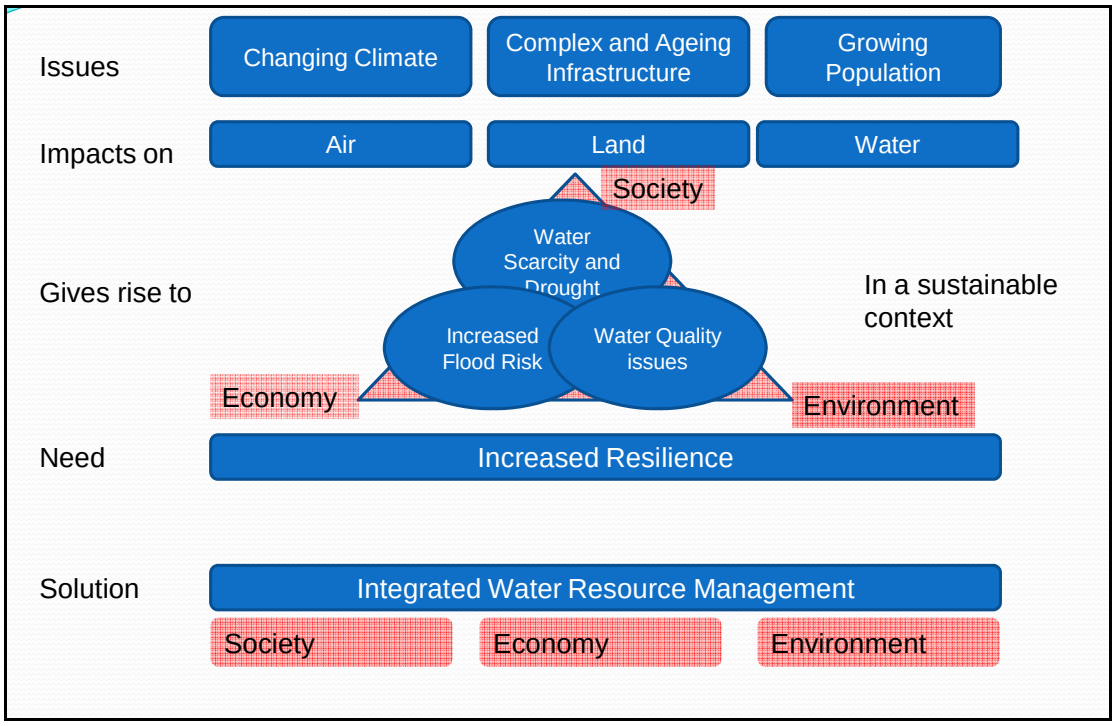
Study of real options and opportunities of developing resilience in catchments

Flexible engineering and infrastructure options - to allow for changing climate and population scenarios

Water and Food interactions – UK and International

In Summary as Figure 9 below

Figure 9 Integrated Water Resource Management



A 5.8 "Sustainability & CC"

(i) Ensuring water sustainability in a changing climate with growing population and competing land pressures

Water, Energy and Food security and sustainability are inexorably linked **(54)** and all are vital to the UK, Government policy and decision making should incorporate all three aspects at the same time, both for the UK and internationally – we have an opportunity to take global leadership

Can we get to viewing waste water as a resource – the 'Bio-refinery' concept - where the water is re-usable, and the sludge is a source of energy and recoverable chemicals and fertilisers **(41)**

Can we reduce the loss of rainfall as a resource, particularly in older urban areas with combined sewerage, where rainfall occupies valuable space in networks (which can result in flooding) and requires pumping and treatment – which results in consumption of energy. How can new approaches such as Sustainable Urban Drainage Solutions (SUDS) be made to 'fit' alongside traditional solutions **(16, 33)**

Need for innovative water and waste water solutions and non-conventional methods of construction which can reduce both embedded carbon and long-term energy consumption **(41)**

Water – need to reduce demand eg domestic consumption via smart meters and tariffs, agriculture and industry consumption via alternative sources and improved technologies (eg re-use) **(25,41)**

Concept of embedded water – in food, manufactured products and energy – need for education to enable improved customer choice in exactly the same way as has been done for carbon, and to introduce the concept of water footprint (both direct and embedded) **(18)**

SUDStype technologies exist – need for econo-financial review and different approach for the UK **(18,33)**

Critical gap in rainfall modelling and prediction of regional scale weather events, linked to Jet Stream variations and blocking highs, causing or ending prolongued droughts and excessive rainfall events (Private communication with climate and weather modellers and reviewer's opinion).

Combined Storm Overflows (CSOs) – need to develop affordable sustainable solutions with real-time management and control, which can prevent gross pollution while reducing the burden on sewerage and treatment systems (Reviewer's opinion)

Need to reduce carbon footprint, especially for waste water **(18)**

A 5.9 "Usage, Energy & Environment"

ii) Achieving optimal water use, supply and waste water treatment in response to these pressures without increasing energy consumption and whilst providing protection for the water environment

Overview/key facts

- 14 reports reviewed with majority being Government/Regulator outputs
- Mainly UK-focused

Summary of the theme's key conclusions and recommendations

Pumping/treating and cleaning water have profound effect on energy use so reducing demand will reduce overall energy use in the water sector(18, p6) as 6% of energy used to pump water (18, p61). This obviously links to the environment via generation of greenhouse gases etc and need for renewable energy.

Good water quality in the environment means less energy is used in treating the water (18, p43).

Close **link** between **water efficiency and energy** - the more "hot" water that is used also affects energy use. Water for personal household washing, cooking and cleaning contributes ~ 35 million tonnes of greenhouse gases per year - over 5% of UK total ***If target both get win/win solution*** – Act on CO_2 campaign. (18, p70).(33,p11)

Water use accounts for 27% of all carbon emissions from the home (17,p8)

Water may be **used** in a wasteful manner because it is not valued correctly. Reducing demand means less water need be taken from the environment. Regulatory recommendations to try and improve understanding of value which also may have beneficial effect on the **environment** include water trading and abstraction licence changes (30,p3, 32,p3, 25,p9 etc)

Desalination could provide a **limitless supply** of fresh water but the **energy** costs are high – need to prioritise and accelerate research into reducing energy costs of desalination (re energy & money) (7)

Any **cost-benefit** analysis of any **water efficiency** proposals needs to take account of wider benefits including the **full value** of water and the potential for **CO2 savings**. (25, p237)

Perennial energy crops (ie for **biofuels**) will generally **use more water** than food crops, potentially impacting on both the ecology and water availability within the catchment (18 p30)

Water trading and unbundling upstream processes could have beneficial environmental, latter account for nearly all environmental impact (30,p9)

Strategic issues, risks or opportunities identified

Multi utility approach to efficiency recommended as 40% of energy used in households is to heat water, (33 p11)
Where possible any energy efficiency initiative should also include hot water efficiency objectives and vice versa. Any CO2 savings should count against either the energy companies' CO2 savings targets or water companies' water efficiency targets and should be factored into any analysis of the costs and benefits of water efficiency measures or to use the CO2 savings against their own Carbon Reduction Commitment (25 , p237)
Opportunities for joint water and energy efficiency retrofit have been missed (17,p22)
Debt in water sector 3x higher than energy sector (25) indicating different customer attitude
Energy efficiency is associated with metering (33,p20)

Quality of evidence presented, exemplar case studies referenced

Most reports for Theme G from accredited organisations with adequate references and the water/environment /energy link addressed in some way in most.
Reference made to Energy Efficiency Initiatives as better exemplars than in Water (ref Energy Saving Trust)

Enablers or barriers to practical application

Enablers
Environment damage was no1 issue in public consultation on coming white paper (24, p1)
Should be synergies between smart metering in water & energy sector (25)

Barriers
New innovative water resource development options tend to be expensive and energy intensive. (17,p8)
Greywater harvesting & some rainwater harvesting systems use energy (18 p38)
Water grid would be highly energy intensive so not supported by DEFRA (18 , p37) may also have environmental issues

Recommendations for implementation of solutions, trials of known technology or short term innovation

Householders should be made aware of water use and energy relationship(18, p70)
Better co-ordination of water efficiency & energy efficiency initiatives

Recommendations for longer term research where vital knowledge is limited and no known or practical solutions are currently available

More use of renewable energy in the water sector (eg from sludge) will help the environment by lowering greenhouse gasses (18, p74)

A 5.10 "High Impact Events"

iii) Responding to changes in frequency and duration of extreme and high impact events (including climatic, natural and human induced events

Summary of the theme's key conclusions and recommendations
Key research and innovation requirements identified are;
Flooding (60, 82)

Integrated drainage systems – especially major infrastructure issues around flooding, private sewers and combined storm overflows.

SUDS in urban and rural areas

Early Warning and flood risk methodologies

Novel engineering solutions

Water Scarcity and Drought (39,81)

Predictive modelling of river flows and resource estimations - close to industry

Drought forecasting, management and contingency planning

Economic impacts

General/Both

Need to consider the costs of infrastructure replacement and adaptation to CC (64)

How will UK food production be impacted by predicted climate change?

Strategic issues, risks or opportunities identified
The balance between water demand and availability has reached a critical level in many areas of Europe (water scarcity). In addition, more and more areas are adversely affected by changes in the hydrological cycle and precipitation patterns (droughts). Over the past thirty years, droughts have dramatically increased in number and intensity in the EU. The number of areas and people affected by droughts went up by almost 20% between 1976 and 2006. The total cost of droughts over the past thirty years amounts to € 100 billion. At least 11% of the European population and 17% of its territory have been affected by water scarcity to date. (**Water Scarcity & Droughts – 2012 Policy Review – Building blocks Non-Paper** - 49**)**

Floods are the most important hazard in Europe in terms of both economic and life loss. In 2002 the direct cost of flooding was EURO 13 billion. The consequences of more severe and frequent floods will be exacerbated by intensive land use including uncontrolled urbanisation. (**WssTP Strategic Research Agenda - 28**)Within the UK at least 6 million properties are currently at risk from flooding and coastal erosion (**Flood and Coastal Erosion Risk Management (FCERM) Research Strategy –** (83)

UK industry main worries about water security were about floods or droughts causing major, long term breakdowns or restrictions in electricity supply (cf. 2003 EU drought and EDF nuclear plant on rivers, Tewksbury flooding of power distribution, Fukishima impact in Japan). Second risk concern was flooding of their own premises or their supply chains (**CDP Water Disclosure 2010 -** 64)

Increased precipitation intensity and variability are projected to increase the risks of flooding and drought in many areas. But the spatial and temporal resolution of predictions is limited and predicting extremes is still very uncertain! (76)

Enablers or barriers to practical application

Enablers

EU Floods and water scarcity reports
Pitt Review(s)
UK CC Act and Adaptation Sub-Committee
EU BLUEPRINT for Water due in 2012
LWEC Flood Research Strategy
EU Water Joint Programming Initiative

Barriers

Climate Change - uncertainty over actual changes at catchment/water company level – but opportunities if got right

Cross Research Council initiatives in infancy – improve close to business knowledge and climate for take up

Need to secure the finances and expertise to deliver the identified research needs, building upon a solid base of past experience and lessons learnt; and to develop and sustain this over the next 20 years (**LWEC FCERM – (**83).

Recommendations for implementation of solutions, trials of known technology or short term innovation

Need to develop integrated land use planning and integrated flood risk infrastructure (60, 18)
Develop further water valuation scenarios, especially for water scarce catchments and extreme events
Improve financial climate for SUDS, wetland solutions, soft engineering and sacrificial land for floods.
Develop risk tools with Insurance industry
Develop monitoring programmes to deliver better modelling capabilities that will support mitigating or adapting to the emerging risk ok of drought (**Scottish Government CAMERAS 2011 –** 84)
Flexible engineering and infrastructure options - to allow for changing climate (**WssTP SRA -** 45)

Recommendations for longer term research where vital knowledge is limited and no known or practical solutions are currently available

Climate change scenarios on water extremes at catchment scale (**WssTP Strategic Research Agenda -** 28)
Study of real options and opportunities of developing resilience in catchments (**A BLUEPRINT to Safeguard Europe's Water Resources – Discussion document – 85**)
Determine the secondary impacts of droughts – land degradation, ecosystem impacts, food provision and security, energy production, economic growth, social stability, etc.(**Global Water Security – An Engineering Perspective - 4**)
Develop drought forecasting tools with indicators and triggers based on regional climatic conditions, vulnerability of use sectors and uncertainties associated with the description of drought events.

A 5.11 "Ecosystems & Biodiversity"

iv) Maintaining and developing ecosystem functions and biodiversity for a sustainable supply of water resources

Summary of the theme's key conclusions and recommendations

Overall, there is little published evidence presented in the reviews that was of direct relevance or made direct reference to the critical role of understanding ecosystem functions and biodiversity in the context of the management of water resources, although it is embedded in the topic of water security and food. Where mention is made, it tends to be at a high (strategic level) that is not translated into practical (engineered) application e.g., "Fragmentation and deterioration of wetlands, and in particular the separation of rivers from their floodplains, has compromised hazard (flood) regulation and many other ecosystem services (NEA Synthesis report 2011, p23, **72**)."

Strategic issues, risks or opportunities identified

There appears to be a mismatch between the high-level strategic goals and objectives of organisations or programmes concerned with provision of water for environmental security and the pragmatic uptake or implementation of these goals i.e., the economic drivers and engineered solutions that are the focus of water resource management are not generally taken into consideration. This may be because adding biodiversity and biogeochemical considerations to physics-led engineering for water resource provision adds a level of complexity (and uncertainty, owing to the quality of the data) that is out of sync with strategic needs. This presents a major risk for sustainable water management. For example, Report 39 (section 2, p4) states: "There is usually sufficient water (in England and Wales) to meet the needs of people and wildlife apart from prolonged periods of dry weather." This appears at odds with the conclusions of the NEA synthesis report and is too high level to add value. Another example are the Catchment Abstraction Management Strategies (CAMS, section 3.2 available water resources p.6) that "consider how much freshwater resource is reliably available, how much water the environment needs and the amount of water already licensed for abstraction" but base this analysis on a purely physical (i.e., volume-based) analysis. Consequently, although 'ecological flows' are considered in the CAMS process, the focus is on the physical balance of available water with no account made of the quality of that water. Hence if the ecological flow of a river is augmented by physical recharge from a particular source, this is regarded as positive even though the source may be degraded (e.g. by agricultural pollution). The NEA (Report 72) states: "Major increases in fertiliser use, particularly nitrogen and phosphorus, have adversely affected aquatic ecosystems through runoff."

Quality of evidence presented, exemplar case studies referenced

The NEA states: "…assessed across the broad range of terrestrial and aquatic habitat types, about 30% of services are currently declining and many others are in a reduced or degraded state" (p 10 UK NEA Synthesis report 72). However, there is little evidence from the reviews that ecosystem functions and biodiversity are a critical element of water resources and sustainable water supply i.e., 'sustainability' receives cursory treatment in the literature. The closest thematic area that attributes some important to the overarching topic is that of food security – probably because of the ongoing debate between use of land for food vs use of land for conservation. It is clear that there is much more to be done on how these are to be integrated under the umbrella of ecosystem services.

Enablers or barriers to practical application

The literature on water delivery in the non-academic sector does not appear to publish evidence for activities connected with ecosystem functioning. This may be because this is largely an 'academic' subject that does not (yet) translate well to pragmatic water resource management but it does point to a mismatch between those concerned with water conservation for ecological functioning (e.g. RSPB, WWF, and parts of Defra and EA) and those concerned with water delivery (i.e. water utilities). There are exceptions e.g., the United Utilities SCaMP project and South West Water's "Upstream thinking" secured through OFWAT PR09 process, which allows them to bill at 65p per customer to generated £9m for catchment restoration (see e.g. http://www.southwestwater.co.uk/index.cfm?articleid=7398), (89).

Recommendations for implementation of solutions, trials of known technology or short term innovation

Changes are needed to the way we undertake the economic value of ecosystems and their 'services' so that a stronger case can be made to the economic water regulator OFWAT in the next periodic review. At a strategic level, these changes are outlined in the NEA synthesis report (Report 72) that calls for more focus on 'contemporary' economic and participatory techniques (NEA synthesis p 13 72) and suggests: "these techniques need to be adopted in everyday decision-making practice." The review of the literature for this topic area suggest there is little evidence for the use of such techniques currently.

Recommendations for longer term research where vital knowledge is limited and no known or practical solutions are currently available

Report 72 NEA states "Reversing declines in ecosystem services will require the adoption of more resilient ways of managing ecosystems, and a better balance between production and other ecosystem services – one of the major challenges is to increase food production, but with a smaller environmental footprint through sustainable intensification." This is quite different thinking to that currently embedded in e.g. IRBM practice and some integration of the various approaches under a 'modern economics' umbrella will be needed long-term. Critical here are:

- Exploring the value of **regulating services**: "While the climate regulation effects of carbon sinks ultimately benefit all of society, ecosystem-based hazard regulation generally provides more localised or directional ('downstream') direct benefits, for example along rivers where exposure to flooding and erosion is reduced by upstream attenuating processes." (NEA synthesis, p34, 72).

- Further consideration of the role of **provisioning services**: "Approximately 66% of the UK's annual water demand of 102 billion cubic metres is met by overseas sources through embedded (virtual) water, three-quarters of which is due to production of agricultural biomass. (NEA synthesis p36, 72).