Adapting to Climate Change 2015

Southern Water

Contents

1. Executive summary

This report has been written in direct response to a questionnaire issued in December 2013 by the Department for Environment, Food and Rural Affairs (Defra) and associated guidance for organisations wishing to update the Government on progress since the first round of climate change adaptation reporting by the water industry in 2011.

The guidance stressed that second round adaptation reporting is voluntary and set out a series of topics with questions covering those areas Defra was inviting second round reporting organisations to provide an update on. Defra recognised that not all questions would be relevant to every organisation, but asked for as much information as necessary on how things have changed since the first round of reporting.

1.1. Understanding climate risk

An update is provided in this report on Southern Water's understanding of climate change risks and their implications for the organisation, attempting to go some way to consider:

- how the organisation's understanding of climate risks, impacts and effects has advanced
- what climate change evidence or research has been used to improve understanding
- the organisation's understanding of climate impact thresholds
- how any assessment and analysis have been achieved.

1.2. Understanding uncertainties

This report also sets out Southern Water's understanding of uncertainties, where possible including:

- those uncertainties that remain in monitoring and evaluation
- newly identified uncertainties
- further implications of uncertainties on the water sector
- any progress made to address information gaps
- any underpinning strategic and technical assumptions.

1.3. Implemented and new actions

An important part of progress updating has been for Southern Water to review previously identified actions to address climate change risks or increase resilience, where possible including assessing whether they have:

- achieved beneficial outcomes
- mitigated climate change risks
- increased readiness to respond and recover from impacts
- contributed to sustainable development.

In doing so, where achievable an attempt has been made to comment on how effective actions have been or if they have resulted in savings as well as wider climate change benefits.

As well as reviewing previously identified actions that have been progressed, the report also provides a valuable update on future climate change adaptation actions.

1.4. Barriers and interdependencies

Southern Water's understanding of barriers and interdependencies is reviewed, including in relation to:

- key barriers to implementing adaptation actions
- how these may have assisted or hindered actions
- newly identified barriers and if these are being addressed.

1.5. Monitoring and evaluating

Southern Water's views on monitoring and evaluation are also considered, including where possible:

- identifying if climate change risks have been embedded
- effectiveness of monitoring and evaluation processes
- potential financial benefits from implementing actions
- whether there is flexibility in adaptation approaches.

1.6. Opportunities and benefits

Opportunities and benefits afforded to the organisation and sector are reviewed, including in relation to:

- actions taken to exploit opportunities
- effectiveness of efforts.

2. Introduction

2.1. Adaptation Reporting Power Round 1

In order to better understand the resilience of key sectors and the way in which they are planning adaptation to climate change, the Department for Environment, Food and Rural Affairs (Defra) instigated a round of climate change reporting that was invoked under the Secretary of State's Climate Change Act 2008 Adaptation Reporting Power (ARP). First round reporting for the water sector under ARP (ARP1) was compulsory for all water and sewerage companies across England and Wales. It resulted in Southern Water compiling and submitting its first Climate Change Adaptation Report to Defra in 2011, in accordance with Defra's requirements and those set out by the EA in supplementary guidance.

2.2. Adaptation Reporting Power Round 2

To continue and broaden the understanding of adaptation planning, in 2013 Defra requested a second round of climate change reporting under ARP (ARP2). This included a request for reporting by certain sectors that had not previously taken part in ARP1, as well as ARP1 reporting sectors. ARP2 reporting by water companies was requested on a voluntary basis and asked to be completed by 2015.

The primary stated aim of reporting for a second round is to provide an understanding of adaptation planning in reporting organisations and the extent to which adaptation actions are being considered and implemented. This will feed into the next National Climate Change Risk Assessment and the National Adaptation Programme (NAP). Progress updates will also help the Government assess the impact the voluntary reporting process is having in terms of supporting organisations to build their climate resilience.

This Climate Change Adaptation Report by Southern Water meets the requirements set out by Defra for those organisations wishing to update the Government on progress since ARP1, including in relation to the following topic areas that repeat reporter organisations were invited to feed back on:

1. Understanding climate risk
2. Understanding uncertainties
3. Details of actions: implemented and new
4. Addressing barriers and understanding interdependencies
5. Monitoring and evaluating
6. Opportunities and benefits.

3. Background to Southern Water

3.1. Company business

The principal activities of Southern Water are:

- water resources
- water treatment
- water distribution
- wastewater collection and surface water management
- wastewater treatment
- sludge treatment, recycling and disposal
- general activities supporting the key business functions.

Southern Water supplies water services to approximately 2.5 million customers and treats and recycles wastewater from approximately 4.6 million people in Kent, East and West Sussex, Surrey, Hampshire and the Isle of Wight. It is one of the UK's major water and sewerage infrastructure providers.

3.2. Water resources, treatment and distribution

The Southern Water area of supply is complex in nature due to the fragmented geographical areas of supply and the inter-connections between its own supply areas as well as those with a number of other water companies. The area supplied by Southern Water covers a total of some 4,450 kilometres squared (km^2), and extends from east Kent, through parts of Sussex, into Hampshire and the Isle of Wight in the west. The total number of people served is approximately 2.5 million.

Water is supplied from 117 sources and treated at 89 water treatment works. The water is distributed via 13,750 km of main and 204 service reservoirs. The average water into supply in 2014–15 was 529 megalitres per day (Ml/d). As a result of demand management policies and leakage reduction, the water into supply has fallen significantly since privatisation from a figure of 730 Ml/d in 1989. The geographically separate supply areas supplied by Southern Water, and also the geographical relationship with other water companies in the region, are shown in Figure 3.1.

Figure 3.1 Southern Water's current area of water supply

Water resources planning takes place at the level of the Water Resource Zone (WRZ) which is the largest area in which all customers bear the same risk of restrictions during drought. There are ten WRZs in the Southern Water area, some of which are connected by means of treated or raw water transfers. The spatial basis for water resources planning within the Southern Water supply area is as follows:

Western sub-regional area (Western area), which includes the following WRZs:

- Isle of Wight
- Hampshire South
- Hampshire Andover
- Hampshire Kingsclere.

Central sub-regional area (Central area), which includes the following WRZs:

- Sussex North
- Sussex Worthing
- Sussex Brighton.

Eastern sub-regional area (Eastern area), which includes the following WRZs:

- Kent Medway
- Kent Thanet
- Sussex Hastings.

Southern Water also has boundaries with seven other water companies.

These are:

- Bournemouth Water
- Wessex Water
- Portsmouth Water
- Thames Water
- Sutton and East Surrey Water
- South East Water, which includes the area of the former Mid Kent Water
- Affinity Water, formerly Folkestone and Dover Water Services.

There are several bulk supplies between the companies.

The majority (70%) of Southern Water's supplies comes from groundwater, predominantly from the chalk aquifer which is widespread across the region. A further 23% comes from river abstractions: most notably the Eastern Yar on the Isle of Wight; the Test and Itchen in Hampshire; the Western Rother in West Sussex; the Eastern Rother in East Sussex; and the Medway and Stour in Kent. The remaining 7% of supplies come from the surface water impounding reservoirs, all of which are owned and operated by the company. The largest of these is Bewl Water. This is a pumped storage reservoir, with water being abstracted from the River Medway, stored and subsequently released as required for re-abstraction further downstream. The reservoir is owned and operated by Southern Water, but South East Water has an entitlement to 25% of the yield.

The other three reservoirs in the Southern Water supply area are Darwell, Powdermill and Weir Wood. Darwell and Powdermill are used to supply the Sussex Hastings WRZ, with Darwell also providing a bulk supply of water to South East Water. Weir Wood, in north Sussex, supplies parts of Crawley and Horsham and also provides bulk supplies to South East Water.

It is winter rainfall that determines the status of sources and hence the ability to abstract water from them. Southern Water is situated in one of the driest regions in the country. Total annual rainfall averages about 730 millimetres a year. However, it is the rainfall during the autumn and winter periods that is critical to the availability of water resources in the region. It is only during this period that rainfall can infiltrate through the soil to recharge groundwater reserves, store river baseflow for the following year and replenish surface water storage.

3.3. Wastewater collection and treatment

Southern Water supplies wastewater services in East and West Sussex, the Isle of Wight, and the majority of Hampshire and Kent, as well as small areas in Surrey. The total population served is approximately 4.6 million and the area covered is 10,550 km^2.

The area is characterised by the long length of coastline (1,250km) and the fact that the majority of the large centres of population are sited on the coast. A number of coastal areas are extremely low-lying, close to, or below mean high water spring tide. The largest of these areas is Portsea Island (Portsmouth). There are other smaller settlements at or near sea-level, particularly in the West Sussex Coastal Plain.

The underlying geology is significant in terms of flood risk and varies from impermeable clays in the Weald, which can lead to flash flooding during intense rainfall, to chalk downland, that can give rise to high groundwater levels and consequent flooding during long periods of continuous rainfall.

The area is served by 365 discrete catchment areas (sewer networks and treatment works). There is no connectivity between these catchments. The total length of sewer (foul, combined and surface water) in these catchments is approximately 21,600 km and includes 2,375 pumping stations.

In October 2011, a further 15,000 km of sewers and laterals transferred to Southern Water and up to 620 private pumping stations will have transferred by October 2016.

Of the 365 works, 277 discharge to water courses, 22 discharge to ground, and the remainder to coastal or estuarine waters. Many of the major treatment works discharge to significant water courses:

- Rivers Medina and Yar on the Isle of Wight
- Test and Itchen in Hampshire
- Arun, Adur and Ouse in Sussex
- Medway and tributaries in Kent.

Most of the major coastal towns and cities are served by coastal works which discharge direct to the marine environment. Nineteen discharge to coastal waters and a further 47 to estuarine waters. Twenty-nine of the works are served by long sea outfalls.

3.4. Sludge treatment and disposal

Southern Water currently treats in excess of 100,000 tonnes of dry solids of sludge per year (tds/yr) and operates 16 sludge treatment centres. All of the company's sites produce cake treated to conventional standards defined by the Safe Sludge Matrix. They range in treatment capacity from 750 to 20,000 tds/yr and it is anticipated that sludge volume will increase by about 10% over the next five year period.

Currently Southern Water produces a conventionally treated product with the aim of recycling all treated sludge (biosolids) to agricultural land. The treatment processes used are mesophilic anaerobic digestion followed either by cake storage or liquid lime dosing into the digested sludge stream to ensure levels of harmful bacteria are reduced.

Southern Water's sludge strategy is to ensure that it has treatment capacity to safely treat and recycle sludge to land for beneficial use as a fertiliser and soil conditioner. The biogas bi-product of sludge treatment is utilised to generate renewable energy, via combined heat and power (CHP) engines, which is used on operational sites or exported to the grid. The company ensures that its sludge is safe to recycle to land and meets all environmental requirements. Currently anaerobic digestion and recycling of sludge to land is recognised as the best practicable environmental option for sludge treatment and disposal. This is because as well as recovering a renewable energy source in the form of biogas, the plant nutrients contained in the sludge are made available to farmers, displacing expensive and unsustainable man-made fertilisers. The strategy is dynamic and developed in line with legislation, product market requirements and the need for business efficiency and the management of risk to the business.

Southern Water's current Business Plan includes provision of treatment capacity for sludge digestion, to meet the demand from an increasing population and tighter environmental standards for treated sewage effluent. The company also plans to replace older CHP engines to ensure they continue to operate efficiently converting gas to electricity.

Looking forward, the sludge strategy will review how emerging technology may allow further improved resource recovery from sewage sludge. Examples of this would be whether the biogas should be introduced to the natural gas supply grid, which would allow much more efficient utilisation of the energy compared with generating electricity. There is also a need to be aware of and plan to comply with future regulatory requirements and possible changes to land availability for sludge recycling.

3.5. Regulatory and legislative framework

The water industry is governed by three principal regulators:

- Ofwat – economic regulator
- Environment Agency (EA)
- Drinking Water Inspectorate (DWI).

The water companies are required to balance the competing demands of improving drinking water quality and environmental standards against the requirements for improving efficiency and customer satisfaction, and cost-benefit analysis for relevant capital expenditure. Tighter quality and environmental standards will often imply increased energy usage and higher consequential carbon dioxide (CO_2) emissions.

All water companies have price limits determined on a five-year cycle with business plans (funding and outcomes) approved by Ofwat. The EA and DWI have significant input into the process in terms of particular environmental and quality issues which require resolution. In addition, customer preference and willingness to pay is increasingly important in shaping business planning and identifying customer promises that need to be met by the company.

For the majority of the company's capital investment, Ofwat requires the demonstration of positive cost-benefit outcomes. Consideration of the costs and benefits of adapting to climate change are therefore included within each individual scheme, which contributes toward the achievement of the outcomes promised in the Business Plan.

The current price review period (Asset Management Plan 6 or AMP6) runs from April 2015 to March 2020. Planning for the next period (AMP7) will commence in 2017–18, with the final business plans agreed late in 2019.

Primary obligations and duties are set out in the Water Industry Act 1991, the Water Resources Act 1991 and the water company licence. The majority of water company activities are governed by a range of legislation that includes:

- Water Industry Act 1991
- Environment Act 1995
- Water Resources Act 1991
- Water Act 2003 (amending the Water Industry Act 1991)
- Flood and Water Management Act 2010
- Environmental Permitting Regulations 2010.

3.6. Organisational structure

The company's key activities, in the context of managing climate change, are:

- Strategy – liaison with regulators and responding to legislative change and on all other strategic issues
- Integrated asset planning and operations – asset management and the day-to-day management of the company's activities
- Capital investment delivery – design and delivery of capital schemes to upgrade or improve water and wastewater infrastructure.

The strategic role is entirely 'in-house'. Asset management is a mixture of in-house, out-sourced partnership working and contracted resources (some design and the majority of construction work). Operational activities are managed by in-house staff, but certain functions are out sourced.

3.7. Stakeholders

Southern Water routinely works with a range of stakeholders across and outside of its region. These range from Government departments such as the Defra, financial and environmental regulators, as well as a range of local and area-wide community stakeholder groups. In formulating its 2015–20 Business Plan, the company engaged with customers and stakeholder groups in an unprecedented manner to ensure that it fully understood and took account of customer and third party views.

Under the Flood and Water Management Act 2010, Southern Water routinely works with the EA, Lead Local Flood Authorities (LLFAs) and other flood risk management authorities, as well as local community groups, to minimise and respond to local flooding issues. This includes working together to reduce long-term flood risks. The company has actively participated in consultations on Flood Risk Management Plans and Strategies and takes an active role in the development of Surface Water Management Plans. In the water resources arena, liaison with stakeholders will continue to ensure optimum outcomes are achieved, taking into account responses to consultations in the water-stressed area of South East of England.

3.8. Supply chain

As part of Southern Water's outcome delivery strategy, the company has put in place a number of agreements with its partners for the AMP6 period (2015–20). These include MWH as Strategic Solutions Partner and three new joint venture Investment Delivery Partners:

- CMDP – Costain and MWH are delivering schemes to maintain and improve water supply and wastewater treatment works (WTWs) in Kent and East Sussex
- GTM – Galliford Try and Imtech, supported by strategic design partner Atkins, are delivering maintenance and improvement schemes at water supply and WTWs in West Sussex, Hampshire and the Isle of Wight
- MGjv – Morrison Utility Services and Galliford Try are delivering investment to expand and maintain water mains and sewers, supported by strategic design partner AECOM.

In addition, the Operations React and Maintain contractors in place for AMP6 are Clancy Docwra (water distribution), Cappagh Browne Utilities (sewerage networks) and BTU (Meica). Laboratory services are provided via two partners, ALS Testing (water) and ALcontrol Laboratories (wastewater). The company's Strategic Recruitment Partner is Matchtech Group.

4. Climate risk

4.1. Introduction

Southern Water has been monitoring and assessing the risks posed by climate change for many years. It was involved in the early UK Water Industry Research (UKWIR) research and development into the impact of changing rainfall patterns on flood risk, Climate Change and the Hydraulic Design of Sewerage Systems, published in 2003. The impact of climate change on water resources has long been recognised and forms a key part of the company's Water Resources Management Plan (WRMP).

The major risks posed by climate change are:

- Flooding, either customer properties, or water company assets
- Stress on water supply, from either increased demand or reduced supply.

A more detailed analysis of the risks posed is presented in Appendices 2, 3 and 4 and discussed in the body of this report. It is important to recognise that, in general, the risks posed by climate change are no different from other pressures (for example growth and new development, environmental stress, existing flooding for example) which are central to the company's business. The scale of threat may be different but there are few new threats.

There are two main policy responses to climate change: mitigation and adaptation. Mitigation addresses the root causes by reducing greenhouse gas emissions, while adaptation seeks to lower the risks posed by the consequences of climatic changes.

4.2. General effects of climate change

Climate change is driven by changes in mean global temperature. Since 1950, global mean temperatures have risen by approximately 0.5 °C. Forecasts for the future range from 2 to 4 °C to year 2100. Appendix 1 shows the summary of expected change in various parameters for 2050 and 2080.

While these increases in temperature may appear relatively small, the consequential impact on other climactic factors, including changing weather patterns could be much more severe.

For the UK, aside from the principal effect of mean temperature, the main direct effects will relate to changing rainfall patterns and an increase in sea level. More extreme weather is likely: periods of longer and more severe drought; increased incidence of extreme rainfall and consequential flooding; wetter winters; increased frequency of heat waves.

For the South East of England, annual average rainfall is expected to remain broadly unchanged to 2080, but this disguises changes in seasonal variation and also in daily and sub-daily rainfall patterns. In summary, winters are likely to be wetter, while summers are likely to be drier. The frequency of short, high-intensity rainfall events is likely to increase in both summer and winter. Changes in seasonal rainfall will potentially affect river levels, with lower river levels in summer impacting water resources and water quality. These effects are likely to have significant consequences for all aspects of the company's operations. Wetter winters may result in higher groundwater levels and associated flooding and increased flows to WTWs.

Appendix 1, figures 1 to 9, shows graphs of low/medium/high scenarios for mean temperature rise, and percentage change in rainfall (winter and summer), illustrating the wide range of possible outcomes.

Southern Water's region has a long coastline and the majority of the main centres of population lie along the coast. Some areas are close to current sea level and in a few cases, below mean high water levels. A number of borehole sources are relatively close to the shoreline and in conditions of extreme drought are vulnerable to saline contamination. Sea-level rise is therefore likely to have an impact on the company's operations, both water and wastewater.

Appendix 1 figure 10 shows projected mean sea level rise around the country.

As well as direct impacts, as forecast by current climate impact models, there are other indirect secondary impacts, which are more difficult to predict but which are nevertheless potentially very significant. These include, for example:

- Redistribution of population (both residential and tourist) as a result of temperature increase or water stress
- Changes in agricultural practice as a result of higher temperatures and a longer growing season
- Increase in algal growth and invasive species disrupting water quality
- Effects of higher temperature on treatment processes (water and wastewater)
- Effects of higher temperature on operation and life expectancy of electrical and other equipment (whether company's own or third party)
- Potential loss of power caused by more extreme events
- More extreme wetting/drying cycles leading to ground movement and consequent structural failure
- Transport and logistical difficulties caused by extreme weather conditions
- Changes in staff working practices arising from higher temperatures.

The effects of climate change are thus very wide ranging, affecting all aspects of the company's operations. However, at a higher level (eg water resource planning or changes in environmental standards) the impact of climate change can be seen as just one element of the need for water and sewerage companies to become increasingly flexible and adaptable to many challenges which may arise in the future.

To that extent, planning for adaptability is already part of 'business as usual' for water and sewerage companies.

4.3. Research

The water industry has been at the forefront of research into the effects of climate change, principally through Water UK and UKWIR. Southern Water is an important contributor to and active member of both Water UK and UKWIR. It influences and takes cognisance of the findings of industry research, including informing climate change adaptation.

Water UK

Water UK set up a Climate Change Focus Group in 2007, to enable all water companies to meet, discuss and progress topics related to climate change impact. Southern Water continues to be represented on this group since its inception.

In 2007 Water UK appointed MWH to prepare a report on climate change impact for the water industry. The published report, A Climate Change Adaptation Approach for Asset Management Planning, included an Excel workbook with three principal tables:

- Climate change impacts on water industry assets
- Adaptation options in response to climate change impacts
- Information source analysis.

The tables covered all aspects of water company business, and identified relevant impacts and responses. This piece of research has been used to inform adaptation reporting.

UKWIR

UKWIR promotes and funds research across all aspects of water company business and on behalf of the water companies in the UK. Each UKWIR technical discipline (water distribution, sewerage, wastewater treatment customers, etc) is co-ordinated by a Programme Lead (from one of the water companies). In 2008, UKWIR recognised the need to bring together all climate change research across the disciplines and appointed a Programme Lead for climate change in early 2009.

One of the earliest pieces of research carried out by UKWIR was the 2003 study into the impact of changing rainfall patterns on flood risk, Climate Change and the Hydraulic Design of Sewerage Systems, reported in 12 volumes plus summary. The study was based on the outputs from UK Climate Projections 1998 (UKCP98), and UKCP02.

This has been updated with UKCP09, but is based on Regional Climate Models (RCMs) to infer short term rainfall intensities. A further review, as part of UKWIR's Project 15 CL10, is due to be completed in 2015. Additional understanding of the role of convectional rainfall in high intensity storms with respect to the joint Meteorological Office / Newcastle University Project Convex is ongoing.

Another key element of work resulted in the report, Climate Change – A Programme of Research for the UK Water Industry, published in 2009. This provided a first climate-related snapshot looking across the UK water industry to 2100. It identified where significant uncertainties in the climate science remain, the nature and extent of impact and business risks, adaptation options and where there are critical knowledge gaps and capacity within the industry. A long-term, integrated, forward looking programme of climate change research needs is recommended that will allow the industry to put in place a sustainable response to adapting to climate change.

Key research projects related to climate change adaptation (either completed, in progress or planned) are:

- Climate Change, the Aquatic Environment and the Water Framework Directive
- Effects of Climate Change on River Water Quality
- Modelling the Effects of Climate Change on Water Quality in Rivers and Reservoirs
- Uncertainty & Risk in Supply/Demand Forecasting
- A Scoping Study to Identify Research Requirements to Assist the UK Water Industry in Dealing with Changing Patterns of Drought
- Assessment of the Significance to Water Resources Management Plans of the UK Climate Projections
- Effect of Climate Change on River Flows and Groundwater Recharge, A Practical Methodology: Synthesis Report
- Climate Change Uncertainty in Water Resource Planning
- Climate Change Implications for Water Treatment
- Climate Change Modelling for Sewerage Networks
- Climate Change and Wastewater
- Impact of Climate Change on Source Yields
- Real-time Machine Learning Approach to Near-term Assessment of Risk of flooding in Urban Areas
- Strategic Infiltration
- UKWIR study Wastewater flows and per capita consumption
- Development of revised run-off model for wastewater
- Real Time Control for sewerage systems
- SuDS Research roadmap for the water industry
- UKWIR SW/01: Separation of Storm and Foul Flows
- Best practice for quantifying load from intermittent discharges
- Rainfall Intensity for Sewer Design
- SW01A – Real-time integrated modelling, monitoring and control
- Framework for Developing a Stormwater Management Business Case
- Overcoming the reliance on short term flow surveys to develop and verify sewer network models
- Economics of Infiltration Reduction.

Southern Water has an active role on all Project Steering Groups and is utilising the findings of this work. From UKWIR Board level down, it will continue to support the focus and direction of UKWIR research with respect to climate change adaptation.

4.4. Risk to operational activities

The principal effects of climate change for the water industry are:

- Increased temperature, and more extreme temperature variation
- Less rainfall, and longer periods of dry weather
- More rainfall, more intense rainfall and increased storminess
- Increased sea level.

Tables 1 to 6 of Appendix 2 show the impact and consequences of these effects on each of the key parts of the company's activities:

- Water resources
- Water treatment
- Water distribution
- Wastewater collection and surface water management
- Wastewater treatment
- Sludge treatment and disposal.

It can be seen from the tables that many of the consequences (for example stress on water resources, or flooding from the sewerage network) can arise from many different aspects of climate change.

The impacts and consequences of climate change can also be considered in terms of:

- Severity - consequences for customers (level of service) or for company (resources, either human or financial)
- Immediacy – how soon the effects may be felt, and whether the onset is likely to be gradual and progressive, or sudden
- Inertia – time required to respond to impact
- Barriers to response – what legislative or regulatory barriers prevent response
- Business as usual – whether the effects of climate change are already embedded in company business.

The risk of the above impact and consequence factors is summarised in Appendix 3, tables 7 to 12.

This forms a risk matrix assessing each of the company's core operational activities.

4.5. Company staff

In the company's last Climate Change Adaptation Report (at the time of ARP1) one of the key impacts of climate change was identified as temperature change and this remains the case. Changes in daily temperature patterns may prompt a change in working practices resulting in an earlier start to the working day. More air conditioning may be required in offices to cope with high ambient temperatures. Long periods of extreme high temperature could cause problems with sickness or heat stress. Extremes of wet or freezing weather may give rise to difficulties in travelling to site or office. These impacts are unlikely to be sudden onset and may not be evident within the next 30 years. Onset is likely to be slow, changes in working patterns are likely to be incremental and barriers to change few.

4.6. Premises and IT

As with staff, the most likely impact of climate change on premises and IT is temperature change. More air conditioning may be required in offices to cope with high ambient temperatures and to prevent over-heating of IT equipment. High ambient temperatures are dealt with elsewhere in the world and there should be no significant barriers to overcome.

4.7. Logistics, power and communications

Severe flooding and storm events are likely to be the principal impact on logistics and power or communications failure. There have been several major events over the past decade that have demonstrated how rapidly normal working practice can be completely disrupted with severe consequences for the public. To a large extent, power and communications are in the hands of third-party suppliers, who will themselves be reviewing the impact of climate change, for example high temperatures in transformers and the impact of high winds or flooding of critical sites.

Southern Water has worked hard to review asset resilience in relation to flooding, power supply and communications. This work was evident during the investment period 2010–15 and is ongoing. Where necessary it includes measures to combat the risk of power outages and loss of communications.

In the case of extreme flooding, transportation of flood defence equipment and bottled water supplies is a key issue. Major events have demonstrated the difficulties of co-ordinating response to major flood events. The Pitt review of the 2007 floods affecting the Midlands and Hull made a number of recommendations affecting all category 1 and 2 responders. Some of the recommendations were incorporated into law through the Flood and Water Management Act 2010 and Southern Water fulfils its duties as a responsible flood risk management authority under the Act.

The Flood and Water Management Act and Flood Risk Regulations 2009 place a firm duty on upper tier local authorities to understand flood risk (through the Preliminary Flood Risk Assessment, Flood Risk and Hazard maps, and Flood Risk Strategies). The Act also places a duty on other flood risk authorities to share data and co-operate with these authorities.

Southern Water has actively engaged with LLFAs on Surface Water Management Plans, and also on the Strategic Flood Management Boards. It will continue to assist the LLFA's in their duties under the Flood Risk Regulations and Flood and Water Management Act.

Water UK set up a task-and-finish group to track progress on the recommendations specific to the water industry. All companies responded to the recommendations and significant steps were taken for example, enabling equipment and resources to be shared between companies in emergencies.

4.8. Customer expectation and bill impacts

Serviceability standards for water supply and wastewater collection have risen significantly since privatisation in 1989. Climate change presents a risk to standards on all fronts: water resource and quality; water distribution; wastewater collection surface water management waste treatment and environmental standards.

While most of the risks arising from climate change can be avoided or alleviated (with the possible exceptions of severe flooding caused by sea level rise or extreme rainfall), the cost of maintaining current standards may be extremely high. This is likely to be reflected in rising customer bills. A balance will therefore need to be achieved between maintaining agreed outcomes and costs, involving all agencies: Government, Ofwat, Consumer Council for Water and water companies.

4.9. Periodic price reviews and business plans

In Southern Water's Business Plan for Price Review 2014 (PR14), covering the AMP6 period 2015-2020, key elements relating to climate change included:

Water resources management planning

In terms of water resources management planning, Southern Water has led the water industry in developing a stochastically based approach to long term planning. This approach has been crucial as a result of the company's operational area sitting within a water scarce region. The WRMP has been updated with climate change predictions from UKCP09 and has adopted a more robust planning technique of looking at the potential droughts of the future. This approach has allowed the company to better understand the natural variability of the current climate, which has been modified in line with climate change guidance. Proposed investment streams are designed to take into account latest climate change predictions.

The targeted outcome is a more resilient water supply system, the resilience of sources to extreme droughts being key to company understanding. Benefits for all options are being assessed over a wide range of climatic events to ensure that they improve the resilience of the system.

Flooding of company assets from sea or surface water (fluvial or pluvial)

Direct flooding of assets, or access to assets, presents a threat in the current climate, but the frequency of severe flooding is likely to increase as a result of climate change. Vulnerable assets may require additional protection, such as earth bunding to reduce the risk of flooding, or mitigation measures to ensure that if a site is flooded, damage is limited and downtime reduced. Such measures might include raising electrical equipment above flood level or providing increased remote monitoring and operation of sites to ensure a quick return to service.

Vulnerability (physical resilience) of wastewater treatment sites was considered in the Business Plan for PR14, and whilst a number of sites were considered at risk, only one (at Gravesend) was considered at sufficiently high risk to required additional physical flood protection.

Data on flood risk is being reviewed and vulnerability to flooding will be reassessed for the next business planning period, feeding into the 2019 Price Review (PR19) for the AMP7 period 2020–2025.

Flooding of properties due to hydraulic overloading of the sewerage network

The funding provision to reduce the risk of flooding in PR14 was subject to 'willingness to pay' studies for customers. While many customers consider that flooding has a serious impact on those affected, in reality it affects relatively few people and consequently customers are generally unwilling to see significant increases in water charges to fund flood alleviation schemes.

Sufficient funding has been made available to achieve outcomes that will mean reductions in the number of properties at risk of internal flooding more frequently than once in ten years, with a reduction of 25 per cent in sewer flooding inside homes and businesses needing to be achieved by Southern Water by 2020. The company has also made a commitment to no increase in the number of incidents of sewer flooding affecting outside areas.

Actions for PR19

Further work will be carried out to develop company thinking and consult customers on the above areas during the PR19 process and beyond.

5. Uncertainties

5.1. Introduction

Southern Water relies heavily on sound science provided by experts on the predicted impacts of climate change. There is, however, significant uncertainty around the exact conditions that might arise, which makes long-term investment planning a challenge. Where there is a marginal uplift in cost the company has traditionally adapted its infrastructure in anticipation of these conditions. This provides a degree of additional resilience without unduly burdening customers with the additional cost of these upgrades.

For example, and where beneficial, the company would consider upsizing a combined sewer to cope with the additional hydraulic load that might arise from an increased forecast intensity of rainfall arising from climate change. These are long-life assets where it is appropriate to make provision, in some cases, at the time of construction. Increasingly the organisation is aiming to improve intelligence of its systems so that it can better manage these risks. On the network side, this involves installing monitoring and control systems such that the company can learn and respond to real-time conditions. A more dynamic and adaptive network has the potential to respond to some of the climate extremes forecast.

5.2. Changes since ARP1 and remaining uncertainties

As indicated in ARP1 reporting round, the general direction of climate change for the South East of England is reasonably well established and has not altered significantly from the UKCP98 and UKCP02 predictions. However, the probabilistic nature of the UKCP09 projections clearly illustrates the uncertainties around quantification of change. Figure 8 in Appendix 1 (medium scenario projections for mean summer precipitation) shows a decline in summer rainfall of about 22% to 2099 for the 50%ile medium emissions scenario. Figures 7 and 9 (low and high scenarios) show about 15% and 30% decline for the 50%ile value. The wider extremes of prediction show a variation of about 5% reduction (67%ile low emissions) to 40% (33%ile high emissions scenario).

As stated at the time of ARP1, dealing with uncertainties of this nature necessitates revision of action plans so that proposals can be periodically revisited and revised to take account of updated climate change projections. It has to be recognised also that climate change is one of many uncertainties which face the water industry. The water industry has to be flexible and adaptable to meet all uncertainties across all aspects of the business.

Long-term plans continue to need to take account of all threats and opportunities, of which climate change is one. Southern Water's 25-year WRMP is a good example of such a long-term plan, as are its Drainage Area Plans on the wastewater side of the business. In terms of managing the risk of flooding, the company has certain obligations under the Flood and Water Management Act 2010 and is working closely with other flood risk management authorities across its region to prepare for, prevent and mitigate the risk of flooding to communities.

There are two key aspects of climate change which are still not well understood, relating to the likelihood of severe drought (rainfall shortfall over a two to three-year span) and the likelihood of increased incidence of extreme high-intensity short duration (sub-daily) rainfall. These two aspects are of considerable importance to the water industry in understanding the threat to water resources and in terms of severe flooding. In addition, they are important in relation to design and implementation of Sustainable Drainage Systems (SuDS) for new development.

With the threat of sea-level rise, action will be needed to protect vulnerable communities in low-lying coastal areas. Raising sea defences may prevent catastrophic flooding at times of extreme high tide, but rising sea-level might also affect groundwater levels. The consequences of higher groundwater levels has been felt in the South East of England particularly over recent winters, with significant inundation of sewerage systems. There is therefore a need for all parties to work together to ensure that adequate land drainage is maintained and improved, particularly when viewed in the context of sea-level rise, and that plans are in place to prepare for, prevent and mitigate the risk of groundwater flooding.

Water company activities are heavily reliant on power, telecoms and transport links, all of which face threats from climate change. The ability of other utilities to adequately adapt to climate change is uncertain and all utilities need to work together. Southern Water is continuing to invest in generating plant at critical operational sites that require back up in the event of power failure.

5.3. Remaining uncertainties in monitoring and evaluating climate risks

In terms of uncertainties that remain in monitoring and evaluating climate risks to the water sector, the approach Southern Water has adopted for strategic planning functions has ensured that (based on the UK knowledge bank) it has made provision for the impact of climate change on current and future operations. The company will continue to incorporate the latest set of climate change predications when plans are updated every five years. The greatest uncertainties therefore remain in the accuracy of the national predictions and how quickly these will become apparent.

5.4. New uncertainties that have come to light

In terms of new uncertainties that have come to light since ARP1, the work Southern Water has undertaken has indicated that natural weather variability has just as big an impact on planning assumptions as climate change impacts. On the water resources side of the business, this variability has been incorporated into the latest WRMP and drought plans. In the next round of strategic plans, further work will be undertaken to define the resilience of systems based on Defra's 4R model, from which the company will undertake to establish the integrated risk arising from the resistance, reliability, redundancy, response and recovery components.

5.5. Further implications of uncertainties

Further uncertainties in climate change will be taken into account in new investment decision making processes, which will focus on using a real options appraisal methodology to ensure that investment made in the near future will allow Southern Water to adapt to different climate change scenarios in the long term. This method of strategic investment planning will also provide the scheduling for any new schemes, which will cater for both growth and climate change adaptation.

5.6. Progress made to address information gaps

As described above, new methodologies for water resource planning have helped fill the information gaps that have been identified from previous planning. Southern Water has developed a refinement plan which sets out the approach and enhancements that the company will carry out between 2015 and 2017 to ensure that both the regulatory and modelling aspects that require refinement of the stochastic rainfall approach have been addressed and that the methodology has been developed in time to be used for PR19. During this time the organisation will work closely with the EA to ensure that the high level concepts are mapped out so as to satisfy both regulatory concerns and meet Southern Water's needs.

5.7. Business and methodological assumptions underpinning analysis of impacts and risks

The approach that has been used for climate change assessment of water resources is compliant with the Water Resources Planning Guidelines (WRPG) as it involved sampling for UKCP09 climate change scenarios to provide a range of possible impacts for all Water Resource Zones. A full description of the sampling methods and approach to impact calculation is provided in Appendix D of Southern Water's WRMP.

There was one key area in which the company's approach to water resource planning has built on the WRPG and that is in assessing how climate change impacts differ across a range of drought types and severities. In many water supply systems, the critical potential effect from climate change on water resources actually relates to the impact that it might have on drought characteristics such as persistence and duration, which are not reflected in the UKCP09 perturbation factors.

The stochastic modelling described previously significantly improved understanding of baseline climatic variability during drought events, particularly in relation to higher return period events. The approach adopted by the company was therefore extended beyond the basic requirements of the WRPG, and used both conventional historic and stochastically generated drought sequences to ensure that the impact of climate change on drought type (eg duration and pattern) was assessed along with the basic dissolved oxygen and severity impact. Each climate change perturbation was thus evaluated against a generated time sequence that included all of the drought sequences of interest to the WRMP process, as described in Appendix D of Southern Water's WRMP.

Whilst this approach provided a much greater reliability in the evaluation of climate change impacts, it did mean that the number of runs of groundwater and conjunctive use water resource models had to be limited for the Eastern Area of Southern Water's region. This was because the effects of climate change were being tested for a wide range of drought types and the baseline modelling had shown that the variability of climate change impacts according to different drought characteristics was likely to be at least as important as the range of climate change scenarios. Compliance with the WRPG was still sought through the use of 'smart sampling', which allowed specific scenarios to be selected on the basis of an initial large number of samples and the assessment of hydrologically effective rainfall (HER) and river flow impacts from those samples.

6. Implemented actions

6.1. Introduction

When Southern Water reported under ARP1, it identified a number of key actions in relation to climate change adaptation. Many of these were actions already embedded in the business. In addition, many had a relatively long-term horizon.

This report sets out to provide an update on progress against these previously identified actions and whether they have afforded greater resilience. Where possible, included is a summary of how effective each action has been in relation to:

- achieving beneficial outcomes
- mitigating climate change risks
- increasing the organisation's readiness to respond and recover from impacts
- contributing to sustainable development

Where possible comment has been provided as to whether actions have been cost effective, resulted in savings or provided a wider non-financial benefit. Tables summarising progress against previously identified ARP1 actions are listed in Appendix 4. The following sub-sections seek to highlight key aspects of progress.

6.2. Water resources

The identified need for increased action on demand management and management of water resources has directly resulted in Southern Water implementing its universal metering programme, whereby customers now pay for the actual water they use. This has seen a greater than expected reduction in water demand. The demand forecast for the future includes the estimated impacts of climate change. Southern Water estimates that the overall impact of climate change at a company level is 8Ml/d, a third of the overall impact of climate change on the supply demand balance. Estimated benefits from metering are 16%, which is 6% greater than estimated in the WRMP.

6.3. Water treatment

The company's WRMP has been updated with the climate change predictions from UKCP09. It has also adopted a more robust planning technique of looking at the potential droughts of the future. This approach has allowed an understanding of the natural variability of the current climate, which has then been modified in line with the climate change guidance. Proposed investment streams are designed to take into account latest climate change predictions and strive towards a more resilient water supply system. The resilience of sources to extreme droughts is key to the company's understanding. The benefits for all options are assessed over a wide range of climatic events, to ensure they improve the resilience of the system.

6.4. Water distribution

Increased storminess potentially resulting in temporary loss of supply meant that Southern Water previously identified a need to undertake analysis of risks for each operational site and to undertake contingency planning for provision of bottled water. Functional continuity plans have been derived for all operational areas and this includes identifying different transportation requirements that need to be put into place to ensure core duties can be carried out. The functional continuity plans and site operating plans for extreme events have significantly improved the reliability of service during some extreme events. These plans have resulted in a reduction in the outage levels during recent extreme events.

6.5. Wastewater collection and surface water management

The consequences of flooding for customers can be severe and caused by hydraulic overload through increased rainfall intensities, increased infiltration or sea level rise, or blockage and collapse of sewers. In recognition of the impact of climate change on rainfall, Southern Water's sewer design now incorporates a standard 20% uplift to accommodate additional rainfall volumes. The company has continued with the development of its sewerage network models and these are adaptive to any change, whether it be due to growth or other causes. Flood risk is frequently under review and Southern Water has been actively engaged in sharing sewer model and Drainage Area Plan data with other flood risk management authorities.

Work has been on-going to mitigate the risk of inundation of key sites. For example in relation to Portsmouth the company has undertaken extensive surface water removal from the combined sewerage system to improve flood resilience and surface water removed now directly discharges to local watercourses.

Blockage and collapse hot spot analysis continues to be undertaken as part of sewer asset management within Southern, together with the monitoring of structural condition of sewers within the network. Significant resources have been devoted to the investigation of catchments inundated by groundwater during the winters and springs of 2012–13, 2013–14 and 2014–15 when very high groundwater levels were experienced. In a number of areas where sewer sealing work has been undertaken, mitigation measures (eg tankering) were only required when groundwater levels were notably higher than previous years, confirming improved resilience of the network. The preparation and implementation of infiltration reduction plans has assisted in identifying and realising opportunities for a holistic approach to managing flood risk.

6.6. Wastewater treatment

Southern Water has assessed all its WTW sites to understand capacity and performance constraints in the near and long term. It has identified and is financed for incremental process improvements that will address changes whether resulting from climate change or other factors. The impact of saline intrusion has been identified at two WTWs and investigations in the catchments are programmed for AMP6.

In relation to the impact of discharges on receiving waters, Southern Water developed its PR14 Business Plan on the EA's National Environment Programme Phase 4 (NEP4) requirements and expectations for NEP5, working closely with the EA to understand the science to support and shape the need for investment.

The risk of direct flooding of treatment sites was reviewed as part of the PR14 business planning process and a cost benefit was undertaken for each mitigation scheme. Functional continuity plans and site operating plans for extreme events have significantly improved the reliability of service during some extreme events.

6.7. Sludge treatment and disposal

Southern Water currently treats in excess of 100,000 tds/yr and operates 16 sludge treatment centres. Monitor and review actions identified in ARP1 are incorporated into the business and the company produces a compliant product for recycling to agricultural land. In AMP6 a comprehensive review of company Sludge Strategy is planned which will take account of any relevant aspects of climate change.

7. New actions

7.1. Introduction

The majority of climate change adaptation actions previously identified under ARP1 still have a relevance to the Southern Water business. This is because many of these were actions already embedded in the business. Allied to this, many had a long-term horizons and required continued focus.

Future climate change adaptation related actions beyond ARP2 are listed in Appendix 4. The following sub-sections seek to highlight key aspects.

7.2. Water resources

The need for increased action on demand management and management of water resources within the water scarce South East of England continues. The company will soon see completion of its universal metering programme, which has already resulted in significantly reduced demand for water across the region. Estimated benefits from metering thus far include a 16% reduction in water consumption by customers.

7.3. Water treatment

Southern Water will continue to update water resource planning and treatment requirements using the latest available climate change predictions. It will also continue to adopt an enhanced planning technique of looking at the potential droughts of the future. This approach has already allowed the company to understand the natural variability of the current climate, which the organisation has then modified in line with climate change guidance.

As this process continues, proposed investment streams will take account of the latest climate change predictions. As the organisation strives towards a more resilient water supply system, the resilience of sources to extremes droughts remains key to its understanding. The benefits for all options will continue to be assessed over a wide range of climatic events, to ensure that they improve the resilience of the system.

7.4. Water distribution

Functional continuity planning to combat extreme weather conditions and climate change will continue. This will include all operational areas and relevant support requirements to maintain core duties. Functional continuity plans and site operating plans for extreme events have already significantly improved the reliability of service during extreme events and the aim is that these plans will continue to result in a reduction in outage levels during extreme events.

7.5. Wastewater collection and surface water management

Sewer design now incorporates a standard 20% peak rainfall uplift to accommodate additional flow volumes. The new information from the Convex Project will be reviewed in light of this.

To further improve the intelligence of its systems, Southern Water has a programme to trial additional monitoring and control systems in AMP6 to enhance the capacity for real time control response and to support a more dynamic and adaptive network.

Two catchments have been identified with priority saline intrusion issues and catchment investigations are planned to identify the significant intrusion locations. AMP6 will also see further groundwater infiltration reduction work on the wastewater network, building on the information collated during AMP5.

7.6. Wastewater treatment

Increased demand may arise from demographic change, or from changes in daily water usage in the longer term. However in Southern Water supplied areas, the universal metering programme has seen an average 16% reduction in water demand. Flow to treatment is constantly monitored at most treatment works and future growth patterns are regularly assessed.

Saline infiltration on coastal sites may present problems for treatment processes. Quality of effluent discharges will continue to be constantly monitored at all WTWs, with enhanced emphasis on higher risk sites. Changes in plant performance are likely to be slow, and to an extent predictable.

The issue of tighter discharge standards at certain sites has been reflected in the PR14 Business Plan, based on NEP4 requirements and expectations in NEP5. Southern Water has been working closely with the EA to understand the science to support and shape the need for investment. The risk of direct flooding of treatment sites was reviewed as part of the PR14 business planning process and a cost benefit was undertaken for each mitigation scheme. The appropriate funding is in place and the investment will be implemented in AMP6.

7.7. Sludge treatment and disposal

Southern Water's Sludge Strategy is programmed to be reviewed in AMP6 and this will give the opportunity to consider potential climate change issues and resilience affecting the strategy.

8. Barriers and interdependencies

Many of the perceived barriers and interdependencies previously identified in ARP1 have not altered, but Southern Water has since developed proposals in its AMP6 plan period (2015-20) to further explore the potential for Integrated Water Cycle Management. This approach seeks to reveal interdependencies at a catchment level over the short, medium and long-term. Two pilot schemes were included in the company's PR14 Business Plan and aim to take account of the pressures that exist currently and in the future.

At the time of ARP1 reporting, two significant barriers to adaptation were identified which are to an extent beyond the means of water companies to resolve alone. The first is cost and the fact that water companies are entirely funded through water and sewerage charges, but are subject to customer pressure to restrict charge increases. The second barrier is the conflict between quality driven improvement and adaptation measures. For example, improvements to wastewater treatment standards to maintain or improve environmental quality of receiving waters can lead to an increase in carbon and energy consumption and hence exacerbate and contribute to climate change. Greater consideration of the overall environmental consequences of water quality improvement schemes is necessary going forward.

As stated at the time of ARP1, with the onset of sea level rise and changing rainfall patterns some communities may not continue to be sustainable in the longer term. Though managing direct flooding from sea level rise and surface water as a result of extreme rainfall are not the responsibility of water companies, it is likely that signs of this type of flooding will show through the failure of the water company sewerage systems. Such assets may become overwhelmed by ground and surface water and there are signs that this is already occurring in low-lying coastal areas in the South East.

The principal barrier to climate change adaptation is likely to be the cost of adaptation measures, and the associated impact on water company customer bills. The current approach of using 'willingness to pay' to drive focus for investment planning is potentially problematic in yielding significant support for funding of longer term adaptation measures, early enough for those measures to be effective. Flooding is recognised as having severe consequences on households affected, but generally impacts relatively few people. Consequently there is likely to be reluctance by the broader customer base to agree to a significant increase in bills to alleviate flooding.

The short-term nature of the current regulatory process is also a potential barrier to adaptation. High levels of certainty are required in water company business plans. There is clearly (and understandably) uncertainty regarding the likely impacts of climate change. The probabilistic nature of the UKCP09 projections provides a view of the uncertainties and potential range of impacts, but does not necessarily provide clear enough evidence of the immediate threats posed. There may be a need to move towards longer-term investment planning within the water sector in order to alleviate the longer-term risk of climate change.

Interdependencies have largely been incorporated into planning methodologies, but the company is aware that third party action and interventions pose a risk in the future. Reliance on third parties is an area we are concentrating on. An example of this is reliance on external power supplies. Key sites already have on-site standby generation or dual supplies to guard against power failure and power companies assess the vulnerability of their own sites to flooding or failure from other causes such as high temperature. The need for mobile generators and on-site fixed generators is periodically reviewed and this assessment is part of Southern Water's standard operating practice.

9. Monitoring and evaluation

9.1. Introduction

Southern Water considers that there are few new risks posed by climate change that are not already built into its day-to-day approach to managing change arising for other reasons. Water companies are required to be flexible and adaptable to meet the challenges of balancing supply and demand, accommodating population growth and meeting changing environmental standards. The periodic price review process is the principal vehicle for considering all challenges and opportunities. The annual reporting requirements to the financial and environmental regulators provide a platform for assessing trends on an annual basis and feed into the investment requirements at each price review.

9.2. Effective consideration of climate change risks and organisational embedding

In terms of water resources management planning, Southern Water has led the industry in developing a stochastically based approach to long term planning. This approach has been crucial as a result of its operational area sitting within a water scarce region. Allied to this, it has rolled out a programme of universal water metering, which has already been shown to significantly reduce consumption. This has in turn reduced the volume of wastewater entering sewerage networks.

During the last few years, and building on previous initiatives, the company has invested in flood and coastal erosion risk management, and this has included:

- Surveying and sealing sewers and manholes in areas susceptible to groundwater flooding
- Continued reduction in internal flooding to properties listed under the water industry's DG5 Register
- Heavy investment in areas of its region such as Portsmouth, to reduce the risk of sewer flooding by removing surface water from the combined sewerage systems.

Recent extreme weather conditions have been handled in an improved manner, despite the severity of groundwater levels. For example, although groundwater levels were significantly above normal in Southern Water's region during the winter of 2014–15, problems with inundated sewers were only experienced at three locations compared to approximately 40 locations impacted during the extreme winter of 2013–14. This significantly reduced impact on the sewer network is testament to the overall investment, planning and preparedness of the organisation.

Despite this good progress, Southern Water aims to improve understanding of how its assets respond to climate change. UK sewer networks for example are designed to a 1 in 30 year level of protection so under extreme weather conditions would be expected to become overwhelmed. There are higher standards of protection for critical national infrastructure. The organisation monitors live weather conditions and takes all reasonable steps pre- and post-event, in order to minimise the impact of extreme weather events on service to customers and the environment. Under such conditions it seeks to restore normal service as quickly as possible. The proposal in AMP6 is to trial wider real time monitoring and managing of assets to better respond (in anticipation of and during) extreme weather events so the company can better adapt to predicted and emerging conditions resulting from climate change.

Investment decision making includes assessment of embedded and embodied carbon, such that Southern Water can make informed choices on how its business affects climate change.

9.3. Organisational monitoring and evaluation processes responsiveness to adaptation

The company's monitoring plan ensures the delivery of schemes identified in its business plans are tracked and reported to regulatory organisations on an annual basis. The organisation also ensures that benefits arising from schemes are evaluated over a set period of time following commissioning.

9.4. Effectiveness of monitoring and evaluation processes in responding to recent extreme weather

Monitoring systems, coupled with response plans and functional continuity plans, have ensured that the organisation's ability to respond to extreme weather events has improved over the course of the past five years. The following table summarises some of the lessons learnt.

Table 9.1 – Southern Water lessons learnt and action taken during extreme events

	Water	Wastewater
Planning for more extreme events	1. Southern Water's WRMP now uses stochastic rainfall models to generate potential droughts of the future, which allows predictive source impact assessment. This is a change of approach from the usual historic perspective and allows investment prioritisation in order to address concerns. 2. The inclusion of this new method in the company's WRMP not only helps to improve the resilience of supply areas, but it also ensures that the options selected for the future also contribute to the overall resilience of the zone. There is continued development of this approach, ready for the next set of plans. 3. Key to planning in the future is whether to base plans on providing a level of service to customers, based on what they are willing to pay, or a level of service to the economy based on what is cost beneficial.	1. Groundwater flooding: work with other flood risk management authorities over the past few winters has allowed development and implementation of effective strategies for dealing with groundwater inundation. 2. These events are helping to bring all of the authorities closer together, to deliver coordinated plans of action and response to these extreme events. 3. Sewer relining strategies have also been effective in identifying and then rectifying those sections of sewer that receive the greatest inundation. This has resulted in a significant reduction in the deployment of tankers, despite groundwater levels breaching trigger points. 4. Investment continues to reduce the number of households at risk from internal flooding. Southern Water is targeting a 25% reduction over the period 2015–20.
Managing response	1. Drought Plans clearly define drought action trigger levels and management actions as the organisation enters, goes through and then recovers from a drought. This statutory planning not only sets out these actions but it also provides examples, using historic droughts, of when these actions would be triggered. 2. With the onset of drought, all water supply companies in the South East of England work together to provide a coherent and consistent message with regard to the impact of the drought and the activities that each company is undertaking to conserve supplies. These messages are provided via the Water Resource South East (WRSE) communication team, whose membership is derived from each of the companies. This group also provided a consistent approach to the implementation of the Temporary Use Bans (TUBS).	1. Groundwater level monitoring, which has been used for decades on the water resource side of the business, is now used to trigger management actions on the sewerage system which particularly suffers from groundwater inundation in Southern Water's area. 2. The company also works with its supply chain to deliver effective solutions for customers. This has resulted in Southern Water and associated supply chain partners developing increasingly innovative solutions. For example, the development and deployment of a portable treatment system has allowed improvements to the quality of flood water before discharging it into the environment.

9.5. Financial benefits from implementing adaptation actions

Some of the new adaptation approaches to extreme weather conditions have contributed to a reduction in costs rather than providing additional financial benefits. An example is the universal metering programme, where the volume of treated water supplied to customers is now lower than at the time of water industry privatisation in 1989.

9.6. Flexibility in adaptation approach to allow alternative courses of action to be pursued

The regulatory system still provides barriers to innovative approaches. Barriers are unintentional and are derived from a desire and need to compare organisations and plans on a consistent basis, rather than a more flexible outcome based approach. In addition, on the wastewater planning side of the water industry, there is the need to move towards longer term planning beyond the five year planning horizon. As a consequence, Southern Water has completed strategic planning covering five, 10 and 25 year time horizons for both water and wastewater services.

10. Opportunities and benefits

The water industry is required to source and supply good quality potable water and to collect, treat and appropriately recycle wastewater to a standard that is not detrimental to the environment. As a consequence, the water industry is heavily regulated.

The majority of Southern Water's business is directly related to the environment, for example through the availability of water resources, response to rainfall and flooding, or impact from treated wastewater effluent discharges. There are therefore relatively few obvious additional opportunities. Having said this, there may be additional opportunities for sludge recycling to agricultural land, to aid water retention and there may be advantages for treatment processes operating at slightly higher temperatures. However, these two examples remain uncertain and it is likely that other pressures may negate any potential opportunities.

Despite this, in AMP6 Southern Water has planned for a performance commitment that relates to the proportion of renewable energy that it generates from all operational energy consumed. The company has committed to maintain this level at 15%, with an array of mitigation measures that deliver a payback of 10 years or better. In preparing its PR14 Business Plan, the organisation identified the following energy efficiency initiatives:

- Data management – development of real time dashboards and virtual works model, to ensure that energy intensive plant operates closer to its optimum efficiency. Automatic meter readers and sub-metering to capture actual consumption at around 1,000 key locations. This is expected to realise 15,967 megawatts per hour (MWh) of energy savings.
- Aeration package enhancements (saving 5,659 MWh).
- Replacement of energy intensive blowers and pumps (saving 4,275 MWh).

Collectively these initiatives are expected to deliver energy reduction savings of 25,901 MWh, thereby reducing reliance on imported grid energy.

11. Summary and conclusions

This Climate Change Adaptation Report meets the requirements set out by Defra for those organisations wishing to update the Government on climate change adaptation planning, including in relation to each of the topics that repeat reporter organisations were invited to feed back on. The primary stated aim of reporting for a second round is to provide an understanding of adaptation planning in reporting organisations and the extent to which adaptation actions are being considered and implemented.

Southern Water and the water industry in general is highly regulated, both financially and environmentall. In addition, water company price review setting and business planning is cyclical, short term and increasingly driven by customer preferences and willingness to pay.

Water usage is driven by existing demand, growth and new development, and water resources are influenced by medium-term (annual) rainfall patterns. Wastewater and surface water collection and treatment is influenced by water consumption and usage, and similarly affected by growth and new development. It is also subject to short-term (daily and sub-daily) rainfall patterns. In the South East of England, significant growth is anticipated, but increase in population will to a large degree be counteracted by Southern Water's universal metering programme, which is already resulting in a significant reduction in per capita consumption of water across its region.

In light of the above issues and the fact that water is a natural resource, the water industry is used to dealing with many uncertainties and is necessarily flexible and adaptive. This, and the increasingly long term planning that is being progressed for water resources and wastewater provision by Southern Water, means that the organisation is well placed to adapt as climatic conditions alter. Indeed, there are arguably few completely new risks posed by climate change, although it is recognised that some risks may well increase because of either increased probability or increased severity. As a result, planning for adaptability is already routine practice for water and sewerage companies including Southern Water.

The principal likely impacts of climate change on Southern Water are from alterations in rainfall patterns (both seasonal/annual and sub-daily) and from sea-level rise along its long coastline. Changes in seasonal and annual rainfall patterns could have a major impact on water resources, while changes in daily and sub-daily rainfall patterns could give rise to increased flooding of company assets, affecting the ability to deliver a service or causing direct flooding of customers' property. In addition, the resilience of power supply and other third party external support is paramount in light of predicted increases in the prevalence and severity of storm conditions.

The demands of increased resource usage, variable short-term weather patterns and longer term climatic change have been the focus of water industry research and development for a number of years. As an active participant in this work, Southern Water is seeking to influence the long term direction of research and innovation and this is an increasingly important focal point for the company. Alongside this, Southern Water is committed to a range of initiatives to reduce its energy consumption, carbon use and greenhouse gas related emissions in order to help mitigate climate change.

12. References

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- UK Climate Change Risk Assessment: Government Report (Defra 2012)
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- UK Water Industry Online Reports Catalogue (UKWIR Website)
- Water Resources Management Plan 2015–40 (Southern Water 2014)

Appendix 1

Extracts from UKCP09 projections for temperature, precipitation and sea level rise

Key findings for South East England, 2050s

(Abstract from UKCP09)

Medium emissions scenario

The wider range is from the lowest to highest value for all emissions scenarios and three (10, 50, and 90%) probability levels for each 30-year time period. Under medium emissions, the central estimate of increase in winter mean temperature is 2.2°C; it is very unlikely to be less than 1.1°C and is very unlikely to be more than 3.4°C. A wider range of uncertainty is from 0.9°C to 3.8°C.

Under medium emissions, the central estimate of increase in summer mean temperature is 2.8°C; it is very unlikely to be less than 1.3°C and is very unlikely to be more than 4.6°C. A wider range of uncertainty is from 1.1°C to 5.2°C.

Under medium emissions, the central estimate of increase in summer mean daily maximum temperature is 3.7°C; it is very unlikely to be less than 1.4°C and is very unlikely to be more than 6.6°C. A wider range of uncertainty is from 1.2°C to 7.4°C.

Under medium emissions, the central estimate of increase in summer mean daily minimum temperature is 3°C; it is very unlikely to be less than 1.3°C and is very unlikely to be more than 5.1°C. A wider range of uncertainty is from 1.2°C to 5.7°C.

Under medium emissions, the central estimate of change in annual mean precipitation is 0%; it is very unlikely to be less than –5% and is very unlikely to be more than 6%. A wider range of uncertainty is from –6% to 6%.

Under medium emissions, the central estimate of change in winter mean precipitation is 16%; it is very unlikely to be less than 2% and is very unlikely to be more than 36%. A wider range of uncertainty is from 1% to 40%.

Under medium emissions, the central estimate of change in summer mean precipitation is –19%; it is very unlikely to be less than –41% and is very unlikely to be more than 7%. A wider range of uncertainty is from –43% to 16%.

Key findings for South East England, 2080s

(Abstract from UKCP09)

Medium emissions scenario

The wider range is from the lowest to highest value for all emissions scenarios and three (10, 50, and 90%) probability levels for each 30-year time period. Under medium emissions, the central estimate of increase in winter mean temperature is 3°C; it is very unlikely to be less than 1.6°C and is very unlikely to be more than 4.7°C. A wider range of uncertainty is from 1.4°C to 5.7°C.

Under medium emissions, the central estimate of increase in summer mean temperature is 3.9°C; it is very unlikely to be less than 2°C and is very unlikely to be more than 6.5°C. A wider range of uncertainty is from 1.4°C to 8.1°C.

Under medium emissions, the central estimate of increase in summer mean daily maximum temperature is 5.3°C; it is very unlikely to be less than 2.3°C and is very unlikely to be more than 9.2°C. A wider range of uncertainty is from 1.4°C to 11.5°C.

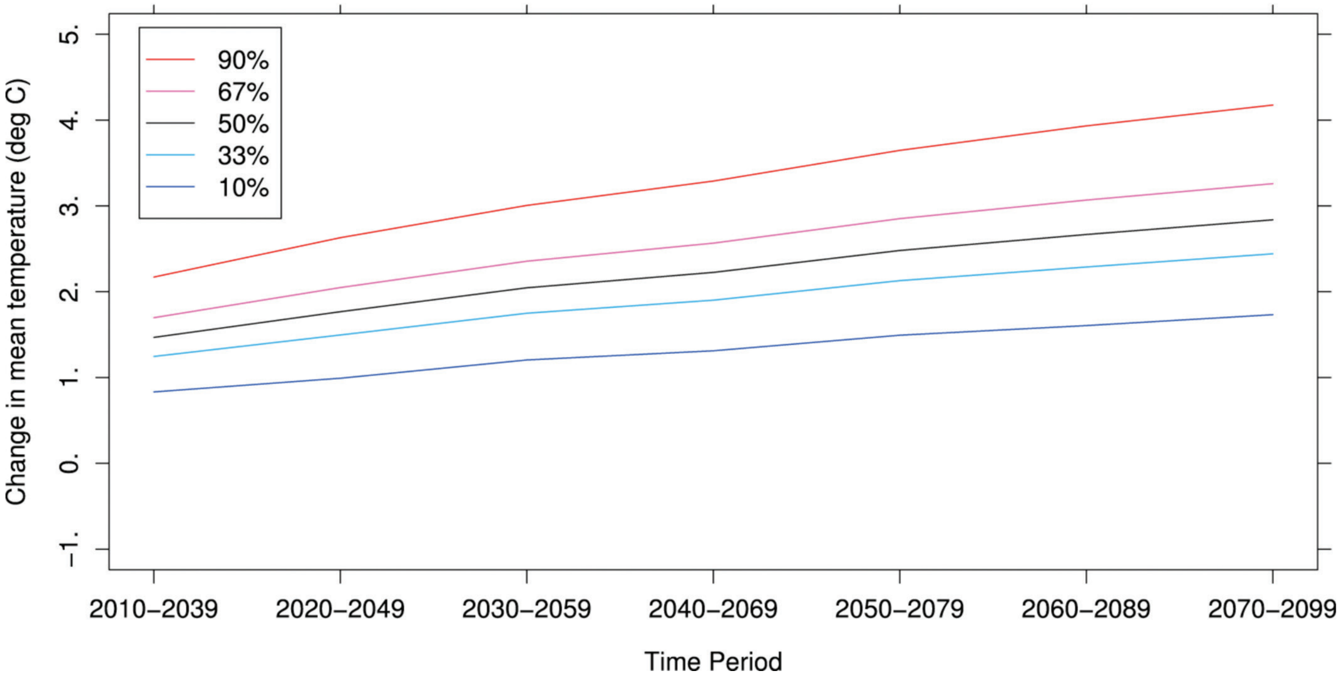
Under medium emissions, the central estimate of increase in summer mean daily minimum temperature is 4.2°C; it is very unlikely to be less than 2.1°C and is very unlikely to be more than 7.2°C. A wider range of uncertainty is from 1.4°C to 9.1°C.

Under medium emissions, the central estimate of change in annual mean precipitation is 1%; it is very unlikely to be less than –5% and is very unlikely to be more than 6%. A wider range of uncertainty is from –7% to 9%.

Under medium emissions, the central estimate of change in winter mean precipitation is 22%; it is very unlikely to be less than 4% and is very unlikely to be more than 51%. A wider range of uncertainty is from 4% to 67%.

Under medium emissions, the central estimate of change in summer mean precipitation is –23%; it is very unlikely to be less than –48% and is very unlikely to be more than 7%. A wider range of uncertainty is from –57% to 13%.

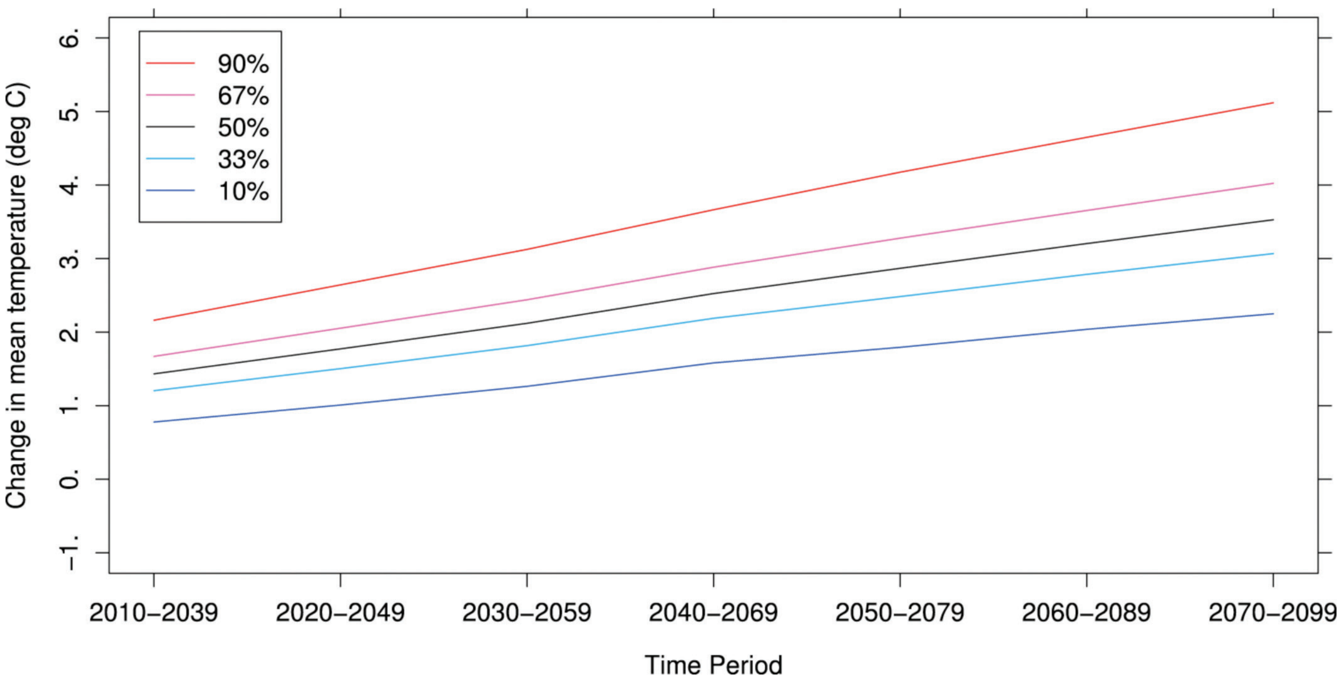
Figure 1 – Mean temperature change – low emissions scenario



Plot Details:

Data Source: Probabilistic Land
Future Climate Change: True
Variables: temp_dmean_tmean_abs
Emissions Scenario: Low
Time Period: 2010–2039, ..., 2070–2099
Temporal Average: ANN
Spatial Average: Region
Location: South East England
Probability Data Type: cdf

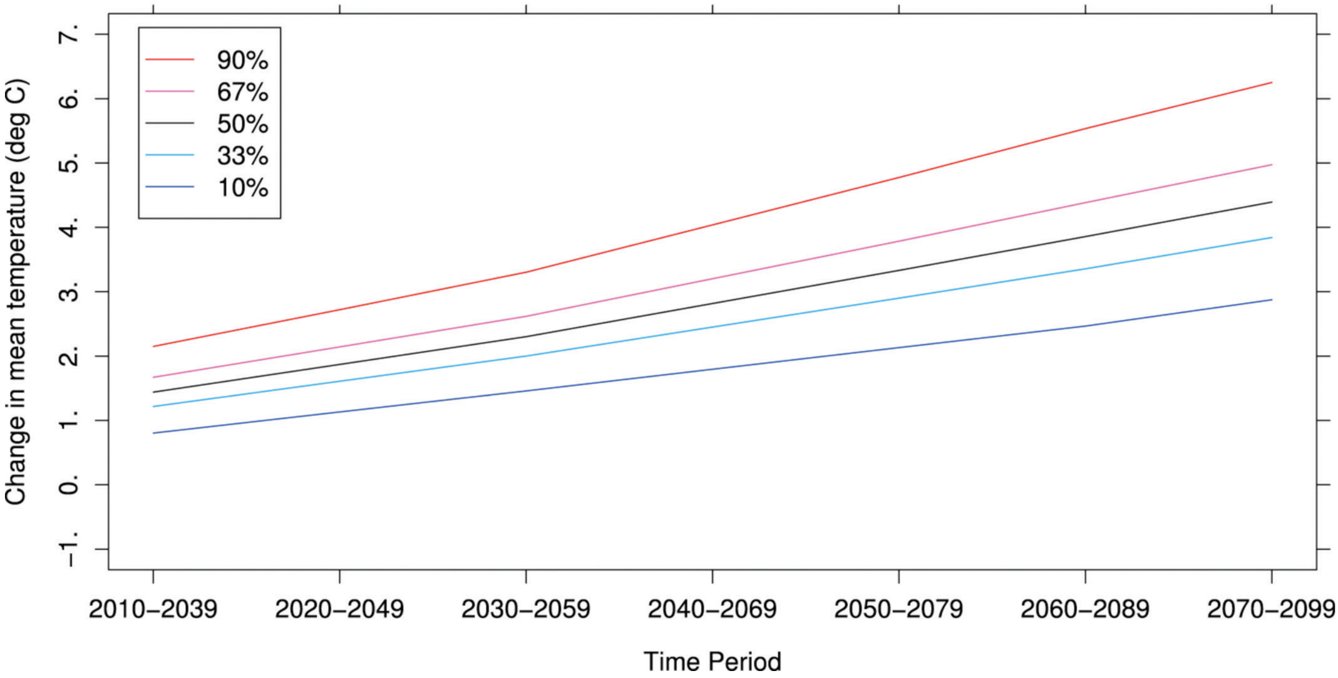
Figure 2 – Mean temperature change – medium emissions scenario



Plot Details:

Data Source: Probabilistic Land
Future Climate Change: True
Variables: temp_dmean_tmean_abs
Emissions Scenario: Medium
Time Period: 2010–2039, ..., 2070–2099
Temporal Average: ANN
Spatial Average: Region
Location: South East England
Probability Data Type: cdf

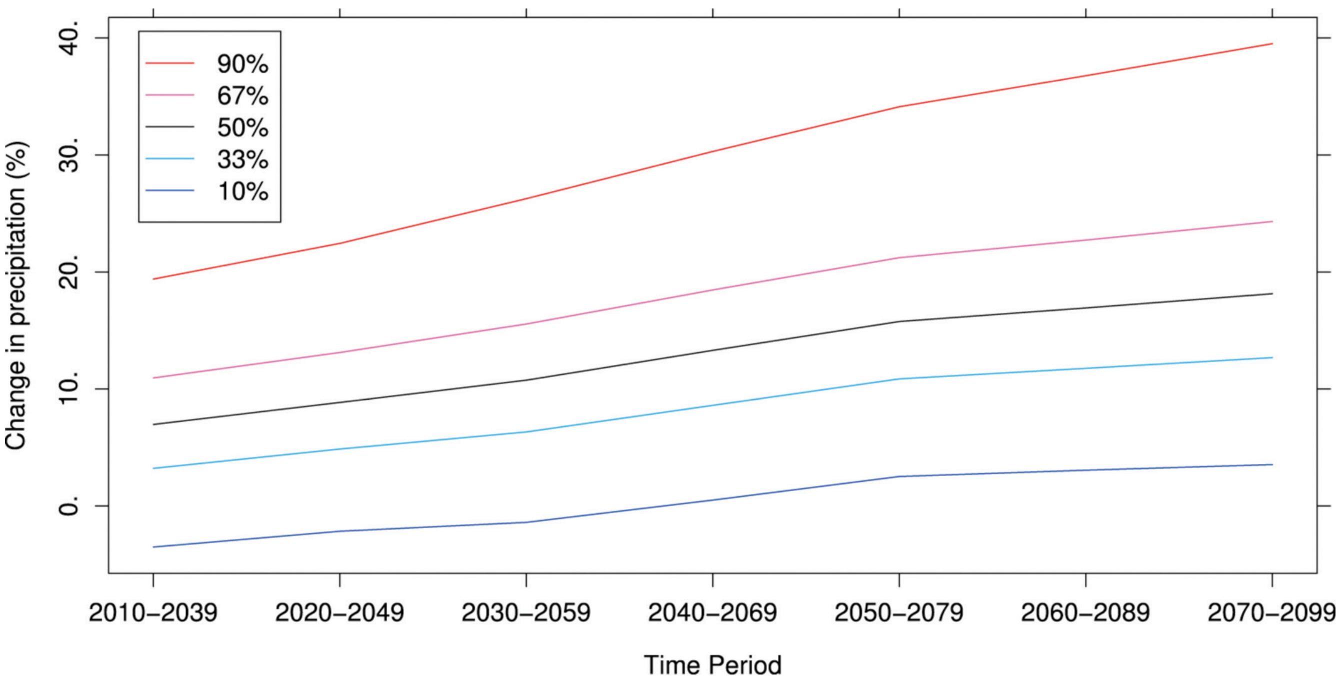
Figure 3 – Mean temperature change – high emissions scenario



Plot Details:

Data Source: Probabilistic Land
Future Climate Change: True
Variables: temp_dmean_tmean_abs
Emissions Scenario: High
Time Period: 2010–2039, ..., 2070–2099
Temporal Average: ANN
Spatial Average: Region
Location: South East England
Probability Data Type: cdf

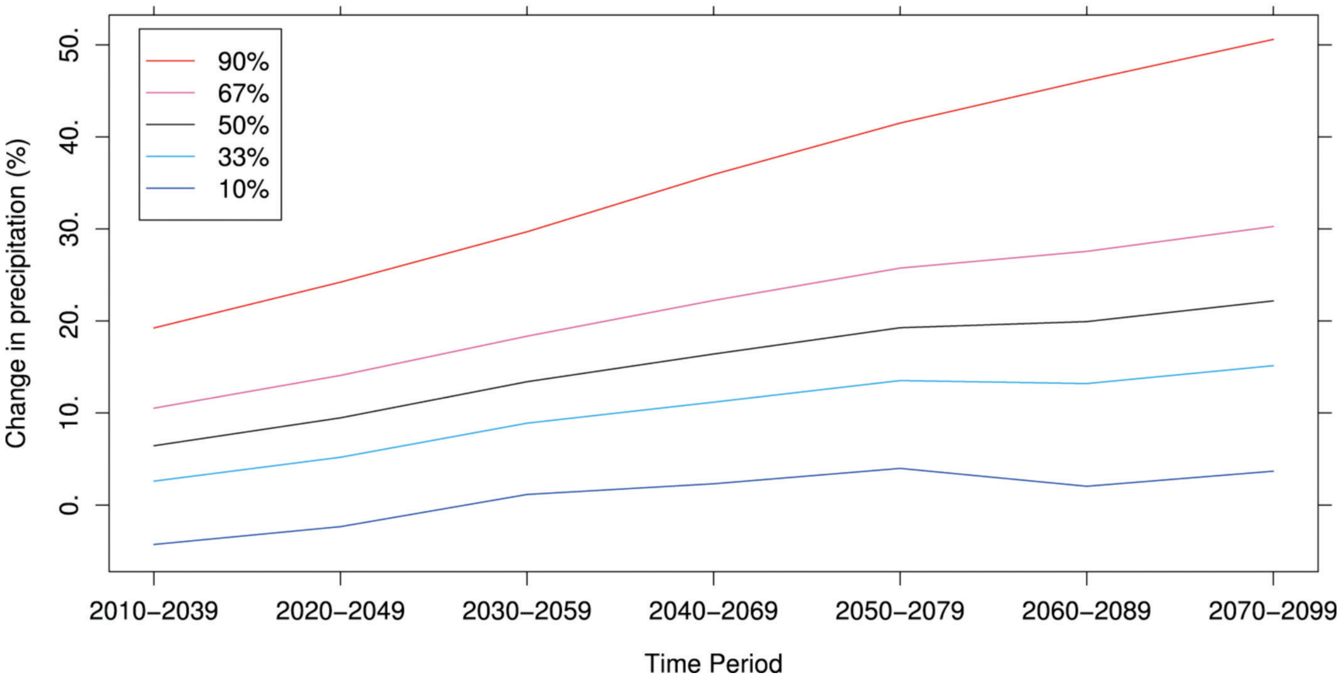
Figure 4 – Change in winter precipitation – low emissions scenario



Plot Details:

Data Source: Probabilistic Land
Future Climate Change: True
Variables: precip_dmean_tmean_perc
Emissions Scenario: Low
Time Period: 2010–2039, ..., 2070–2099
Temporal Average: DJF
Spatial Average: Region
Location: South East England
Probability Data Type: cdf

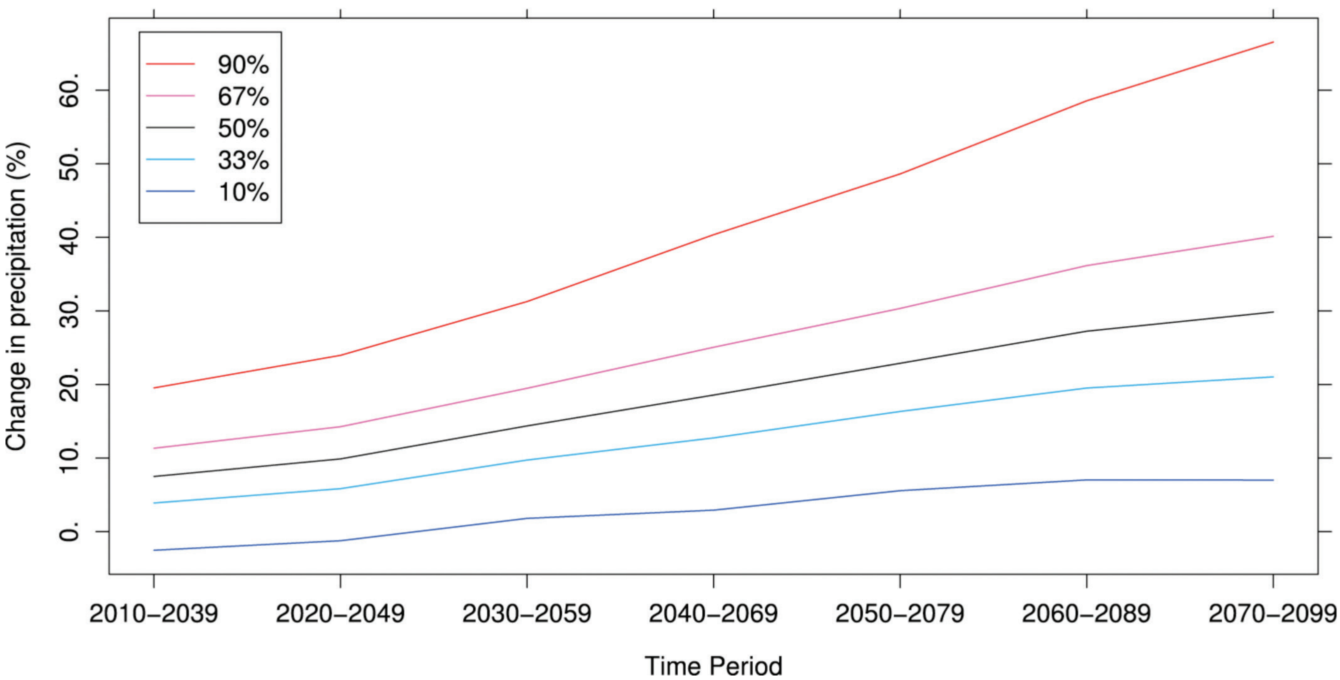
Figure 5 – Change in winter precipitation – medium emissions scenario



Plot Details:

Data Source: Probabilistic Land
Future Climate Change: True
Variables: precip_dmean_tmean_perc
Emissions Scenario: Medium
Time Period: 2010–2039, ..., 2070–2099
Temporal Average: DJF
Spatial Average: Region
Location: South East England
Probability Data Type: cdf

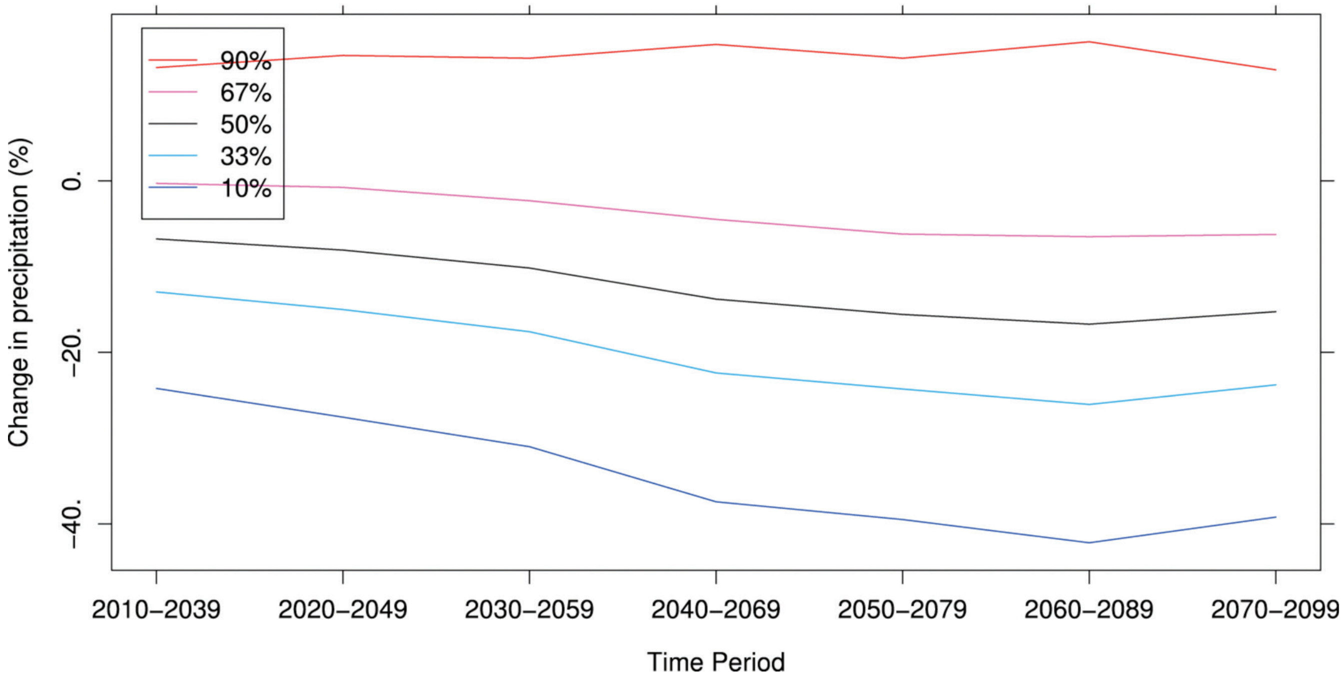
Figure 6 – Change in winter precipitation – high emissions scenario



Plot Details:

Data Source: Probabilistic Land
Future Climate Change: True
Variables: precip_dmean_tmean_perc
Emissions Scenario: High
Time Period: 2010–2039, ..., 2070–2099
Temporal Average: DJF
Spatial Average: Region
Location: South East England
Probability Data Type: cdf

Figure 7 – Change in summer precipitation – low emissions scenario

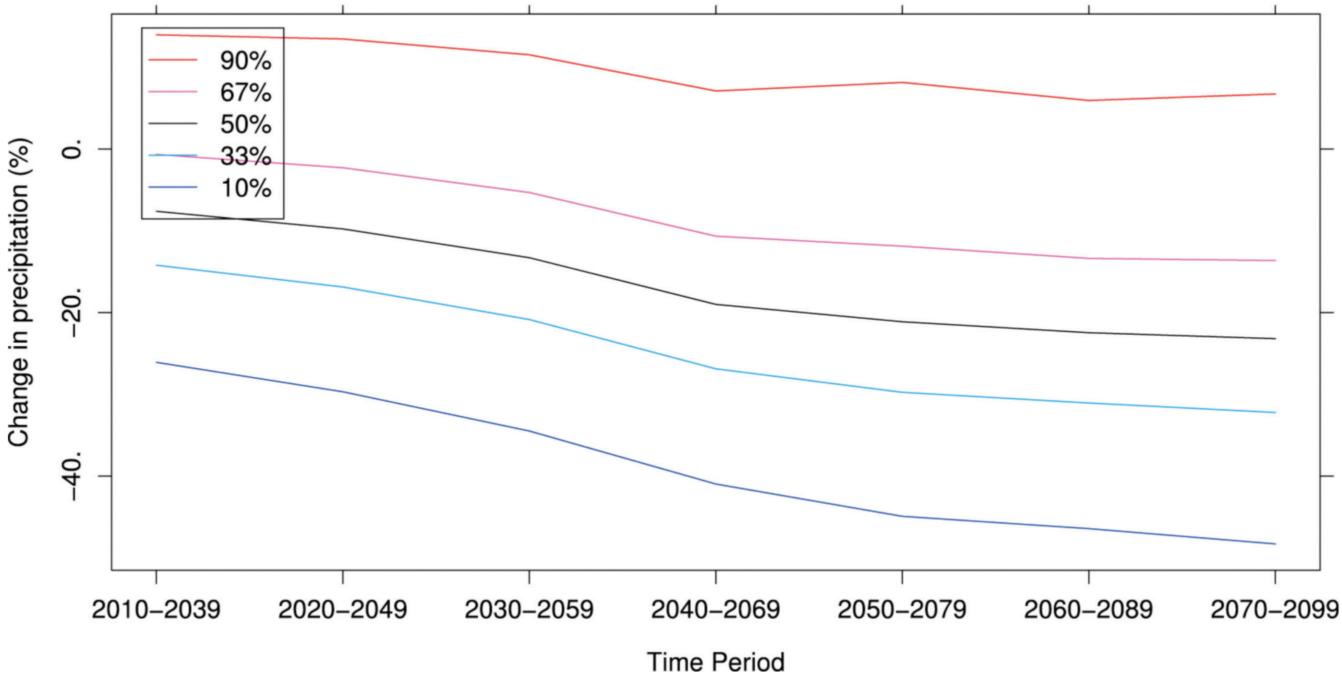


Plot Details:

Data Source: Probabilistic Land
Future Climate Change: True
Variables: precip_dmean_tmean_perc
Emissions Scenario: Low
Time Period: 2010–2039, ..., 2070–2099
Temporal Average: JJA
Spatial Average: Region
Location: South East England
Probability Data Type: cdf

UK CLIMATE PROJECTIONS

Figure 8 – Change in summer precipitation – medium emissions scenario



Plot Details:

Data Source: Probabilistic Land
Future Climate Change: True
Variables: precip_dmean_tmean_perc
Emissions Scenario: Medium
Time Period: 2010–2039, ..., 2070–2099
Temporal Average: JJA
Spatial Average: Region
Location: South East England
Probability Data Type: cdf

UK CLIMATE PROJECTIONS

Figure 9 – Change in summer precipitation – high emissions scenario

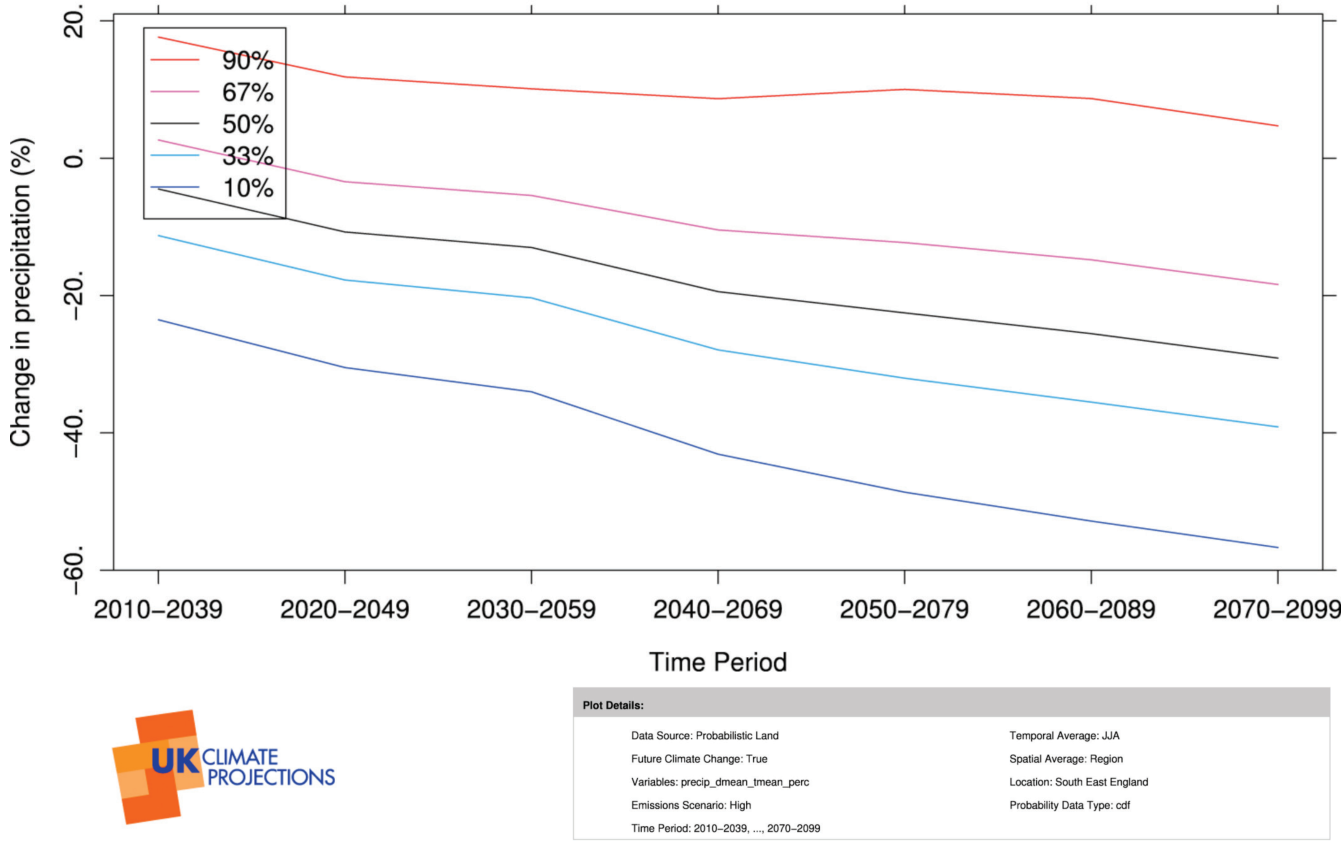


Figure 10 – Central estimate for relative sea-level change

	London			Cardiff			Edinburgh			Belfast		
	High	Med	Low	High	Med	Low	High	Med	Low	High	Med	Low
2000	3.5	3	2.5	3.5	2.9	2.5	2.2	1.6	1.2	2.3	1.7	1.3
2010	7.3	6.2	5.3	7.3	6.2	5.3	4.7	3.5	2.6	4.9	3.8	2.8
2020	11.5	9.7	8.2	11.5	9.7	8.2	7.5	5.7	4.3	7.8	6	4.6
2030	16	13.5	11.4	15.9	13.4	11.4	10.7	8.2	6.1	11.1	8.6	6.6
2040	20.8	17.5	14.8	20.8	17.5	14.8	14.2	10.9	8.2	14.7	11.4	8.7
2050	25.8	21.8	18.4	25.9	21.8	18.4	18	13.9	10.5	18.6	14.5	11.1
2060	31.4	26.3	22.2	31.4	26.3	22.2	22.1	17.1	13	22.9	17.8	13.7
2070	37.2	31.2	26.3	37.1	31.1	26.3	26.6	20.6	15.7	27.4	21.4	16.5
2080	43.3	36.3	30.5	43.3	36.2	30.5	31.4	24.4	18.6	32.3	25.3	19.6
2090	49.7	41.6	35	49.7	41.6	35	36.5	28.4	21.8	37.6	29.4	22.8
2095	53.1	44.4	37.3	53.1	44.4	37.3	39.2	30.5	23.4	40.3	31.6	24.5

Appendix 2 Tables of climate change effect, impact and consequence

Table 1. Water resources			
Climate change effect			
Increased temperature and more extreme variation in temperature	**Changes in rainfall patterns**		**Sea level rise**
	Less rainfall or longer dry periods	**More rainfall, or more intense rainfall (increased storminess)**	
Impact: • Demographic change (resident/tourist population moving from stressed to less stressed areas) • Changes in domestic water use (eg more showers) • Increased garden watering • Increased evapo-transpiration Consequence: • Potential increased demand or reduced supply with consequent stress on water resources	Impact: • Reduction in annual average rainfall • More frequent periods of drought • Seasonal variability leading to less summer rainfall, more winter rainfall • Lower summer river flows • Lower borehole recharge Consequence: • Potential reduced supply with consequent stress on water resources	Impact: • Direct flooding of water supply sites • Loss of power supply Consequence: • Risk of immediate loss of supply for a period of hours or potentially weeks • Potential contamination of water supply	Impact: • Saline intrusion into boreholes • Change in tidal limits of rivers and increased salinity Consequence: • Potential reduced supply with consequent stress on water resource
Impact: • Invasive species in rivers and reservoirs • Increased algal and other biological growth Consequence: • Potential requirement for changes in the storage and treatment of raw water		Impact: • Logistic and transport difficulties • Structural damage Consequence: • Risk to supply for period of hours or days	Impact: • Direct flooding of water supply sites Consequence: • Risk of immediate loss of supply for a period of hours or potentially weeks

Table 2. Water treatment

Climate change effect			
Increased temperature and more extreme variation in temperature	**Changes in rainfall patterns**		**Sea level rise**
	Less rainfall or longer dry periods	**More rainfall, or more intense rainfall (increased storminess)**	
Impact: • Demographic change (resident/tourist population moving from stressed to less stressed areas) • Changes in domestic water use (eg more showers) • Increased garden watering Consequence: • Potential increased demand with consequent stress on water treatment capacity	Impact: • Changes in domestic water use (eg more showers) • Increased garden watering Consequence: • Potential changes in daily water usage patterns and possible increase in peak demand putting stress on the treatment processes	Impact: • Direct flooding of water supply sites • Loss of power supply Consequence: • Risk of immediate loss of supply for a period of hours or potentially weeks • Potential contamination of water supply	Impact: • Saline intrusion into boreholes • Change in tidal limits of rivers and increased salinity Consequence: • May affect the level of treatment processes required
Impact: • Increased microbiological action Consequence: • Potential effect on treatment processes; discolouration and odour problems		Impact: • Poor raw water quality during heavy rainfall, particularly from river sources Consequence: • May affect the level of treatment processes required	Impact: • Direct flooding of water supply sites • Loss of power supply Consequence: • Risk of immediate loss of supply for a period of hours or potentially weeks • Potential contamination of water supply
Impact: • Concern over raw water quality leading to higher potable water standards Consequence: • May affect the level of treatment required		Impact: • Logistic and transport difficulties • Structural damage Consequence: • Risk to supply for period of hours or days	
Impact: • Increased wetting and drying cycles and consequent ground movement Consequence: • Additional investment may be required to protect and maintain structures.			

<table>
<tr><th colspan="4">Table 3. Water distribution</th></tr>
<tr><th colspan="4">Climate change effect</th></tr>
<tr><th rowspan="2">Increased temperature and more extreme variation in temperature</th><th colspan="2">Changes in rainfall patterns</th><th rowspan="2">Sea level rise</th></tr>
<tr><th>Less rainfall or longer dry periods</th><th>More rainfall, or more intense rainfall (increased storminess)</th></tr>
<tr><td>Impact:
• Demographic change (resident/tourist population moving from stressed to less stressed areas)
• Changes in domestic water use (eg more showers)
• Increased garden watering
Consequence:
• Potential increased peak demand with consequent stress on water distribution capacity</td><td>Impact:
• Changes in domestic water use (eg more showers)
• Increased garden watering
Consequence:
• Potential changes in daily water usage patterns and possible increase in peak demand putting stress on the distribution system</td><td>Impact:
• Direct flooding
• Loss of power supply
Consequence:
• Risk of immediate loss of supply for a period of hours or potentially weeks
• Potential contamination of water supply</td><td>Impact:
• Direct flooding
• Loss of power supply
Consequence:
• Risk of immediate loss of supply for a period of hours or potentially weeks
• Potential contamination of water supply</td></tr>
<tr><td>Impact:
• Increased microbiological action
Consequence:
• Potential reduction in water quality between treatment process and customer</td><td></td><td>Impact:
• Logistic and transport difficulties
• Structural damage
Consequence:
• Risk to distribution system for period of hours or days</td><td></td></tr>
<tr><td>Impact:
• Increased wetting and drying cycles and consequent ground movement
Consequence:
• Additional investment may be required to protect and maintain pipelines and to manage leakage</td><td></td><td></td><td></td></tr>
</table>

Table 4. Wastewater collection and surface water management

Climate change effect			
Increased temperature and more extreme variation in temperature	**Changes in rainfall patterns**		**Sea level rise**
	Less rainfall or longer dry periods	**More rainfall, or more intense rainfall (increased storminess)**	
Impact: • Demographic change (resident/tourist population moving from stressed to less stressed areas) • Changes in domestic water use (eg more showers) **Consequence:** • Potential increased peak demand with consequent stress on wastewater collection capacity	**Impact:** • Changes in domestic water use (eg more showers) **Consequence:** • Potential changes in daily water usage patterns and possible increase in peak demand putting stress on the wastewater collection system	**Impact:** • Direct flooding • Flooding of low lying pumping stations • Loss of power supply **Consequence:** • Risk of increased flooding of customers' properties (both internal and external), highways and public open space • Risk of immediate failure of collection system for a period of hours or potentially weeks	**Impact:** • Direct flooding • Flooding of low lying pumping stations • Loss of power supply **Consequence:** • Risk of increased flooding of customers' properties (both internal and external), highways and public open space • Risk of immediate failure of collection system for a period of hours or potentially weeks
Impact: • Increased microbiological action **Consequence:** • Risk of increased attack from H_2S affecting structural condition of pipelines • Risk of increased odour resulting in customer complaints	**Impact:** • Longer dry periods **Consequence:** • Potential for greater deposition of solids and consequent blockage leading to flooding and pollution	**Impact:** • Higher groundwater table in winter **Consequence:** • Potential for increased infiltration	**Impact:** • Increased sea level preventing free discharge of surface water **Consequence:** • Potential requirement for pumped outfalls at extreme high tide levels
Impact: • Increased wetting and drying cycles and consequent ground movement **Consequence:** • Additional investment may be required to protect and maintain pipelines and to manage infiltration		**Impact:** • Logistic and transport difficulties • Structural damage **Consequence:** • Risk to collection system for period of hours or days	**Impact:** • Higher groundwater table in winter **Consequence:** • Potential for increased saline infiltration

Table 5. Wastewater treatment

Climate change effect			
Increased temperature and more extreme variation in temperature	**Changes in rainfall patterns**		**Sea level rise**
	Less rainfall or longer dry periods	**More rainfall, or more intense rainfall (increased storminess)**	
Impact: • Demographic change (resident/tourist population moving from stressed to less stressed areas) • Changes in domestic water use (eg more showers) **Consequence:** • Potential increased demand with consequent stress on wastewater treatment capacity	**Impact:** • Changes in domestic water use (eg more showers) **Consequence:** • Potential changes in daily water usage patterns and possible increase in peak demand putting stress on the treatment processes	**Impact:** • Direct flooding of wastewater treatment sites • Loss of power supply **Consequence:** • Risk of immediate loss of treatment for a period of hours or potentially weeks • Potential pollution of receiving waters	**Impact:** • Higher groundwater table in winter **Consequence:** • Potential for increased saline infiltration and consequent effect on treatment processes
Impact: • Increased microbiological action **Consequence:** • Potential effect on treatment processes; and poor effluent quality • Potential increased H_2S attack on concrete structures	**Impact:** • Lower river flows during summer **Consequence:** • Potential requirement for tightened effluent standards	**Impact:** • Logistic and transport difficulties • Structural damage **Consequence:** • Risk to treatment processes for period of hours or days	**Impact:** • Direct flooding of wastewater treatment sites • Loss of power supply **Consequence:** • Risk of immediate loss of treatment for a period of hours or potentially weeks • Potential pollution of receiving waters
Impact: • Concern over receiving water quality leading to higher effluent standards **Consequence:** • May affect the level of treatment processes required			
Impact: • Increased wetting and drying cycles and consequent ground movement **Consequence:** • Additional investment may be required to protect and maintain structures.			

Table 6. Sludge treatment and disposal

Climate change effect			
Increased temperature and more extreme variation in temperature	**Changes in rainfall patterns**		**Sea level rise**
	Less rainfall or longer dry periods	**More rainfall, or more intense rainfall (increased storminess)**	
Impact: • Greater risk of odour complaints (onsite and when applied to land) Consequence: • Additional investment may be required to mitigate impact.	Impact: • May increase the demand for biosolids to improve dry soil Consequence: • Beneficial	Impact: • Increased risk of 'spoiling' sludge stockpiles creating an unusable product and increasing costs to return to a stable cake Consequence: • Additional investment may be required to protect sludge stockpiles	Impact: • None
Impact: • Increased risk of septicity in sludge making sludge difficult to treat Consequence: • Additional investment may be required to treat sludge to required standards		Impact: • Increased summer rainfall may make getting onto the land to spread biosolids more difficult Consequence: • Alternative disposal routes may be required, with consequent increased investment	
Impact: • Change in crops types grown which may not require biosolids application (eg salad crops, vineyards etc) Consequence: • Alternative disposal routes may be required, with consequent increased investment			

Appendix 3 **Risk Matrix**

Table 7. Water resources

Climate change effect

Business function	Climate variable (eg increase in temperature)	Primary impact of climate variable (eg health)	Severity	Immediacy	Inertia	Barriers	Business as usual
Water resources	Increase in temperature	Demographic change or increased demand for water	High	Medium	Medium	Medium	Yes
		Invasive species or increased microbial action	Low	Low	Low	Medium	Yes
	Less rainfall	Reduced water resource	High	Medium	Low	Medium	Yes
	Increased storminess	Direct flooding of supply sites	Medium	Medium	Low	Low	Yes
		Loss of power supply	Medium	Medium	Low	Low	Yes
		Logistic and transport difficulties	Low	Low	Low	Low	Yes
	Sea-level rise	Saline intrusion in boreholes, and reduced supply	High (in coastal areas)	Low	Low	Low	Yes
		Direct flooding of supply sites	High (in coastal areas)	Low	Low	Low	Yes

Table 8. Water treatment							
Climate change effect							
Business function	**Climate variable (eg increase in temperature)**	**Primary impact of climate variable (eg health)**	**Severity**	**Immediacy**	**Inertia**	**Barriers**	**Business as usual**
Water treatment	Increase in temperature	Demographic change or increased demand for water	Medium	Low	Low	Low	Yes
		Increased microbial action	Low	Low	Low	Low	Yes
		Poor raw water quality	Low	Low	Low	Low	Yes
		Increased wetting and drying cycles and consequent ground movement	Low	Low	Low	Low	Yes
	Less rainfall	Increased water usage (eg garden watering)	Medium	Low	Low	Low	Yes
	Increased storminess	Direct flooding of treatment sites	Medium	Medium	Low	Low	Yes
		Loss of power supply	Medium	Medium	Low	Low	Yes
		Logistic and transport difficulties	Low	Low	Low	Low	Yes
	Sea-level rise	Saline intrusion in boreholes, and poor raw water quality	High (in coastal areas)	Low	Medium	Medium	Yes
		Direct flooding of treatment sites	High (in coastal areas)	Low	Medium	Medium	Yes

Table 9. Water distribution							
Climate change effect							
Business function	**Climate variable (eg increase in temperature)**	**Primary impact of climate variable (eg health)**	**Severity**	**Immediacy**	**Inertia**	**Barriers**	**Business as usual**
Water distribution	Increase in temperature	Demographic change or increased demand for water	Medium	Medium	Low	Low	Yes
		Increased microbial action	Low	Low	Low	Low	Yes
		Increased wetting and drying cycles, and consequent ground movement	Medium	Low	Low	Low	Yes
	Less rainfall	Increased water usage (eg garden watering)	Medium	Low	Low	Low	Yes
	Increased storminess	Direct flooding	Low	Low	Low	Low	Yes
		Loss of power supply	Medium	Medium	Low	Low	Yes
		Logistic and transport difficulties	Low	Low	Low	Low	Yes
	Sea-level rise	Direct flooding	Low	Low	Low	Low	Yes

Table 10. Wastewater collection and surface water management

Climate change effect							
Business function	**Climate variable (eg increase in temperature)**	**Primary impact of climate variable (eg health)**	**Severity**	**Immediacy**	**Inertia**	**Barriers**	**Business as usual**
Wastewater collection and surface water management	Increase in temperature	Demographic change or increased demand for water	Low	Low	Low	Low	Yes
		Increased microbial action and consequent increase from H_2S attack	Medium	Low	Low	Low	Yes
		Increased wetting and drying cycles, and consequent ground movement	Low	Low	Low	Low	Yes
	Less rainfall	Increased water usage	Low	Low	Low	Low	Yes
		Longer dry periods and potential for increased blockage rates in sewers	Medium	Low	Low	Low	Yes
	Increased storminess	Direct flooding of property and company assets	High	High	Medium	Medium	Yes
		Loss of power supply	Medium	Medium	Low	Low	Yes
		Logistic and transport difficulties	Medium	Medium	Low	Low	Yes
	Sea-level rise	Direct flooding of property and company assets	High (in coastal areas)	Low	Medium	Medium	Yes
		Increased sea level preventing free discharge of surface water	High (in coastal areas)	Low	Medium	Medium	Yes
		Higher groundwater table	High (in coastal areas)	Low	Medium	Medium	Yes

Table 11. Wastewater treatment							
Climate change effect							
Business function	**Climate variable (eg increase in temperature)**	**Primary impact of climate variable (eg health)**	**Severity**	**Immediacy**	**Inertia**	**Barriers**	**Business as usual**
Wastewater treatment	Increase in temperature	Demographic change or increased demand for water	Low	Low	Low	Low	Yes
		Increased microbial action	Low	Low	Low	Low	Yes
		Potential increased impact on receiving water (lower river flows)	Medium	Low	Low	Medium	Yes
		Increased wetting and drying cycles, and consequent ground movement	Low	Low	Low	Low	Yes
	Less rainfall	Increased water usage	Low	Low	Low	Low	Yes
	Increased storminess	Direct flooding of treatment sites	Medium	Medium	Low	Low	Yes
		Loss of power supply	Medium	Medium	Low	Low	Yes
		Logistic and transport difficulties	Low	Low	Low	Low	Yes
	Sea-level rise	Higher groundwater table, potential increase in saline intrusion	High (in coastal areas)	Low	Medium	Medium	Yes
		Direct flooding of treatment sites	High (in coastal areas)	Low	Medium	Medium	Yes

Table 12. Sludge recycling

Climate change effect							
Business function	**Climate variable (eg increase in temperature)**	**Primary impact of climate variable (eg health)**	**Severity**	**Immediacy**	**Inertia**	**Barriers**	**Business as usual**
Sludge recycling	Increase in temperature	Increased odour or septicity	Low	Low	Low	Low	Yes
		Change in crop types which may not require biosolids application	Medium	Low	Low	Low	Yes
	Less rainfall	May increase demand for biosolids to improve dry soil	Low	Low	Low	Low	Yes
	Increased storminess	Increased risk of spoilage of sludge stockpiles	Low	Low	Low	Low	Yes
		Logistic and transport difficulties	Low	Low	Low	Low	Yes

Appendix 4 Tables summarising progress against ARP1 actions and actions beyond ARP2

Table 13. Water resources

Business function	Climate variable (eg increase in temperature)	Primary impact of climate variable (eg health)	Threshold(s) above which this will affect your organisation	Likelihood of threshold(s) being exceeded in the future and confidence in the assessment	Potential impacts on organisation and stakeholders	Proposed action to mitigate impact	Timescale over which risks are expected to materialise and action is planned	Progress on implementation of actions	Assessment of extent to which actions have mitigated risk	Benefits / challenges experienced	Future action?
Water resources	**Increase in temperature**	Demographic change or increased demand for water	Water resource planning has to be flexible and adaptive to any change (whether resulting from climate change or other causes)	The supply/demand balance is constantly under review, regardless of climate change impact	Increased action on demand management, and management of resources	Covered by Water Resources Management Plan	Changes in demand for water are continuous as is action to mitigate impact	Implemented customer metering scheme, with greater than expected reductions in water demand. Demand forecast for future includes estimated impacts of climate change	Actions undertaken to date have contributed to overall reduction in demand and have helped mitigate future climate change impacts	Estimated benefits from metering are 16%, which is 6% greater than estimated in the WRMP	Yes
		Invasive species or increased microbial action	Unknown	Unknown	Increased costs to deal with issue	Continuous monitoring of water quality	No known timescale – reactive response	Invasive species work has highlighted need for precautionary action to stop raw water transfer from Bewl Water to Darwell reservoir	This work will be completed by 2020		Yes
	Less rainfall	Reduced water resource	Water resource planning has to be flexible and adaptive to any change (whether resulting from climate change or other causes)	The supply/ demand balance is constantly under review, regardless of climate change impact	Increased action on demand management, and management of resources	Covered by Water Resources Management Plan	Changes in demand for water are continuous as is action	WRMP updated with UKCP09 climate change predictions and more robust planning technique of looking at the potential droughts of the future has allowed better understanding of natural variability of the current climate. This has been modified in line with climate change guidance. Additional bankside storage has been developed to improve resilience of supplies to Hardham WSW	Proposed investment streams are designed to take into account latest climate change predictions. As the company moves towards a more resilient water supply system, the resistance of our sources to extremes droughts is key to understanding. Benefits for all options are assessed over a wide range of climatic events to ensure that they improve the resilience of the system	Planning for future droughts using our new, innovative stochastic approach provides improved understanding of types of future droughts and how climate change might affect these. This has indicated that natural variability has a greater range of impacts than climate change, which provides an improved understanding of the best interventions to make in the future	Yes

Table 13. Water resources – continued

Business function	Climate variable (eg increase in temperature)	Primary impact of climate variable (eg health)	Threshold(s) above which this will affect your organisation	Likelihood of threshold(s) being exceeded in the future and confidence in the assessment	Potential impacts on organisation and stakeholders	Proposed action to mitigate impact	Timescale over which risks are expected to materialise and action is planned	Progress on implementation of actions	Assessment of extent to which actions have mitigated risk	Benefits / challenges experienced	Future action?
Water resources	Increased storminess	Direct flooding of supply sites	Variable depending on site	Increased storminess will cause increased flooding	Temporary loss of supply	Analysis of risk for each site, contingency plans for provision of bottled water	Business as usual to deal with existing threat	Individual site risk assessments have been carried out and protective measures are to be put in place at four sites by 2020	The actions that have been identified will be put in place during 2015 to 2020	The benefits from putting these actions in place will ensure that the sites will be protected against a 1:200 year flood event	Yes
		Loss of power supply	Immediate impact	Dependent on third party suppliers	Temporary loss of supply	Analysis of risk for each site, contingency plans for provision of bottled water, on-site generation for high-risk sites	Business as usual to deal with existing threat	Assessment of back-up power supplies at our strategic sites has been carried out and mobile hook up connections have been made available	Risks have been reduced at each site via the contingency planning process	This has resulted in robust contingency planning that is adhered to in the event of power supply loss	Yes
		Logistic and transport difficulties	Variable depending on site	Increased storminess will cause increased flooding	Temporary loss of supply	Analysis of risk for each site, contingency plans for provision of bottled water	Business as usual to deal with existing threat	Functional continuity plans have been derived for all operational areas	The functional continuity plans and site operating plans for extreme events have significantly improved the reliability of our service during some extreme events	The benefits of these plans have resulted in a reduction in the outage levels during some of these extreme events	Yes
	Sea-level rise	Saline intrusion in boreholes, and reduced supply	Water resource planning has to be flexible and adaptive to any change (whether resulting from climate change or other causes)	The supply/ demand balance is constantly under review, regardless of climate change impact	Increased action on demand management, and management of resources	Covered by Water Resources Management Plan	Changes in demand for water are continuous as is action	Risk of saline intrusion in coastal aquifers can severely restrict yields when groundwater levels are low. May have to adapt short term abstraction arrangements to protect supplies in the future. Previously successful at Balsdean water supply works	Current risk of saline intrusion is covered in the DWSPs, which are updated regularly, including after breach events, and assign an element of risk to each component	Continuous update of actual water quality results, but the assessment does not forecast to predict future issues. Pumping around high/spring tides reduces the risk of increased conductivity, while still managing to meet demand	Yes
		Direct flooding of supply sites	Variable depending on site	Sea-level rise will cause increased flooding	Temporary loss of supply	Analysis of risk for each site, contingency plans for provision of bottled water	Business as usual to deal with existing threat	Individual site risk assessments have been carried out	No sites have been identified that will suffer from flooding as a result of sea level rise	No actions required	Yes

Table 14. Water treatment

Business function	Climate variable (eg increase in temperature)	Primary impact of climate variable (eg health)	Threshold(s) above which this will affect your organisation	Likelihood of threshold(s) being exceeded in the future and confidence in the assessment	Potential impacts on organisation and stakeholders	Proposed action to mitigate impact	Timescale over which risks are expected to materialise and action is planned	Progress on implementation of actions	Assessment of extent to which actions have mitigated risk	Benefits / challenges experienced	Future action?
Water treatment	Increase in temperature	Demographic change or increased demand for water	Water resource planning has to be flexible and adaptive to any change (whether resulting from climate change or other causes).	The supply/demand balance is constantly under review, regardless of climate change impact	Increased action on demand management, and management of resources	Covered by Water Resource Management Plan	Changes in demand for water are continuous as is action to mitigate impact.	Future demand forecasts include estimated impacts of climate change	WRMP assesses vulnerability of water resources to climate change and provides solutions for future climate change challenges	Impact of climate change is two fold, with an increase in demand and decrease in resource	Yes
		Increased microbial action	Unknown	Unknown	Increased costs to deal with issue	Continuous monitoring of water quality	No known timescale – reactive response	Ongoing triple validation water quality monitoring implemented at supply works results in automatic shutdown if trigger levels breached	DWSPs updated regularly, including after breach events, and assign an element of risk to each component	Assessment of actual water quality results does not forecast to predict future issues	Yes
		Poor raw water quality	Unknown	Unknown	Increased costs to deal with issue	Continuous monitoring of water quality	No known timescale – reactive response	Ongoing continuous water quality monitoring. The triple validation system will shutdown the site if the raw water turbidity exceeds set parameters	DWSPs updated regularly, including after breach events, and assign an element of risk to each component	Assessment of actual water quality results does not forecast to predict future issues	Yes
		Increased wetting and drying cycles and consequent ground movement	Unknown	Unknown	Increased costs to deal with issue	Periodic review of structural condition of assets	No known timescale – reactive response	Swallow holes have opened and impacted service reservoirs, particularly in Kent. Additional geomorphologic surveys and new foundations or re-location of structures have mitigated effects	The actions that have taken have improved the resistance of the new structures that have been put in place	Challenges for the future will be to understand whether there are other areas across the region that could suffer from swallow holes or landslips	Yes
	Less rainfall	Increased water usage (e.g. garden watering)	Water resource planning has to be flexible and adaptive to any change (whether resulting from climate change or other causes)	The supply/demand balance is constantly under review, regardless of climate change impact	Increased action on demand management, and management of resources	Covered by Water Resources Management Plan	Changes in demand for water are continuous as is action	WRMP updated with UKCP09 climate change predictions and more robust planning technique of looking at the potential droughts of the future has allowed better understanding of natural variability of the current climate, which we have then modified in line with the climate change guidance	Our proposed investment streams are designed to take into account latest climate change predictions and as we strive towards a more resilient water supply system, the resistance of our sources to extremes droughts is key to our understanding. Therefore the benefits for all options are assessed over a wide range of climatic events to ensure that they improve the resilience of the system	Planning for future droughts using our new, innovative stochastic approach provides improved understanding of types of future droughts and how climate change might affect these. Our work has indicated that natural variability has a greater range of impacts than climate change, which provides an improved understanding of the best interventions to make in the future	Yes

Table 14. Water treatment – continued											
Business function	**Climate variable (eg increase in temperature)**	**Primary impact of climate variable (eg health)**	**Threshold(s) above which this will affect your organisation**	**Likelihood of threshold(s) being exceeded in the future and confidence in the assessment**	**Potential impacts on organisation and stakeholders**	**Proposed action to mitigate impact**	**Timescale over which risks are expected to materialise and action is planned**	**Progress on implementation of actions**	**Assessment of extent to which actions have mitigated risk**	**Benefits / challenges experienced**	**Future action?**
Water treatment	**Increased storminess**	Direct flooding of treatment sites	Variable depending on site	Increased storminess will cause increased flooding	Temporary loss of supply	Analysis of risk for each site, contingency plans for provision of bottled water	Business as usual to deal with existing threat	Individual site risk assessments have been carried out	Difficult to fully quantify	Some actions by third parties have increased the risk of flooding to our sites, e.g. Sandown WSW	Yes
		Loss of power supply	Immediate impact	Dependent on third party suppliers	Temporary loss of supply	Analysis of risk for each site, contingency plans bottled water, on-site generation for high-risk sites	Business as usual to deal with existing threat	Assessment of back-up power supplies at our strategic sites has been carried out and mobile hook up connections have been made available	No further actions have been highlighted	Greater resilience to power supply interruptions	Yes
		Logistic and transport difficulties	Variable depending on site	Increased storminess will cause increased flooding	Temporary loss of supply	Analysis of risk for each site, contingency plans for provision of bottled water	Business as usual to deal with existing threat	Functional continuity plans derived for all operational areas	The functional continuity plans and site operating plans for extreme events have significantly improved the reliability of our service during some extreme events	The benefits of these plans have resulted in a reduction in the outage levels during some of these extreme events	Yes
	Sea-level rise	Saline intrusion in boreholes, and poor raw water quality	Variable depending on site	Sea-level rise will cause increased saline intrusion	Increased costs to deal with issue (additional treatment requirements or alternative supplies	Continuous monitoring of water quality (business as usual)	Dependent on rate of sea level rise	Risk of saline intrusion in coastal aquifers can severely restrict yields when groundwater levels are low. May have to adapt short term abstraction arrangements to protect supplies in the future	Current risk of saline intrusion is covered in the DWSPs, which are updated regularly, including after breach events, and assign an element of risk to each component	Continuous update of actual water quality results, but the assessment does not predict future issues	Yes
		Direct flooding of treatment sites	Variable depending on site	Sea-level rise will cause increased flooding	Temporary loss of supply	Analysis of risk for each site, contingency plans for provision of bottled water	Business as usual to deal with existing threat	Individual site risk assessments have been carried out	No sites have been identified that will suffer from flooding as a result of sea level rise	No actions required	Yes

Table 15. Water distribution

Business function	Climate variable (eg increase in temperature)	Primary impact of climate variable (eg health)	Threshold(s) above which this will affect your organisation	Likelihood of threshold(s) being exceeded in the future and confidence in the assessment	Potential impacts on organisation and stakeholders	Proposed action to mitigate impact	Timescale over which risks are expected to materialise and action is planned	Progress on implementation of actions	Assessment of extent to which actions have mitigated risk	Benefits / challenges experienced	Future action?
Water distribution	**Increase in temperature**	Demographic change or increased demand for water	Water distribution networks have to be flexible and adaptive to any change (whether resulting from climate change or other causes)	The impact of demand on the network is constantly under review, regardless of climate change impact	Increased action on demand management, and management of the network	Progressive improvements to the network to mitigate the impact of higher water usage, and consequent lower pressure	Changes in demand for water are continuous as is action to mitigate impact	Implemented customer metering scheme, with greater than expected reductions in water demand. Demand forecast for future includes estimated impacts of climate change	Actions undertaken to date have contributed to overall reduction in demand and have helped mitigate future climate change impacts	Estimated benefits from metering are 16%, which is 6% greater than estimated in the WRMP	Yes
		Increased microbial action	Unknown	Unknown	Increased costs to deal with issue	Continuous monitoring of water quality	No known timescale – reactive response	Ongoing continuous monitoring	DWSPs updated regularly, including after breach events, and assign an element of risk to each component	Assessment of actual water quality results does not forecast to predict future issues	Yes
		Increased wetting and drying cycles, and consequent ground movement	Unknown	Unknown	Increased leakage and increased costs to deal with issue	Continuous monitoring of leakage	Leakage from the network is continuously monitored as is action to mitigate impact	Swallow holes have opened, particularly in Kent, including one large enough to take the supporting soil matrix around a strategic water main, which broke and supplies to customers were lost. Due to the swallow hole size and number of services affected an immediate repair to the main was not possible	An improved recovery plan underpinned by an overland supply option has been developed. Although this does not eliminate the risk it does improve our response time to these types of incidents	Challenge for the future will be to understand whether there are other areas across the region which could suffer from swallow holes or landslips	Yes
	Less rainfall	Increased water usage (e.g. garden watering)	Water distribution networks have to be flexible and adaptive to any change (whether climate change or other causes)	The impact of demand on the network is constantly under review, regardless of climate change impact	Increased action on demand management, and management of the network	Progressive improvements to the network to mitigate the impact of higher water usage, and consequent lower pressure	Changes in demand for water are continuous as is action to mitigate impact	Since privatisation over 25 years ago, our water supply volume is down by some 200Ml/d, reducing the pressure on the water distribution network. Demand reduction has resulted from drive to reduce leakage from 235 Ml/d to 84 Ml/d and success of the universal metering programme	The drive down on leakage has resulted in a 66% reduction since privatisation and an overall 24% reduction in the amount of water that we have put into supply. Over this period the number of customers that we serve has increased	Benefits from our leakage, water efficiency and metering programmes has resulted in a 24% reduction of the amount of water we put into supply today compared with 1989	Yes
	Increased storminess	Direct flooding	Variable depending on site	Increased storminess will cause increased flooding	Temporary loss of supply	Analysis of risk for each site, contingency plans for provision of bottled water	Business as usual to deal with existing threat	No distribution mains have been impacted	No further action required		Yes
		Loss of power supply	Immediate impact	Dependent on third party suppliers	Temporary loss of supply	Analysis of risk for each site, contingency plans for provision of bottled water, on-site generation for high-risk sites	Business as usual to deal with existing threat	Assessment of back-up power supplies at our strategic sites has been carried out and mobile hook up connections have been made available	No further actions have been highlighted		Yes
		Logistic and transport difficulties	Variable depending on site	Increased storminess will cause increased flooding	Temporary loss of supply	Analysis of risk for each site, contingency plans for provision of bottled water	Business as usual to deal with existing threat	Functional continuity plans derived for all operational areas	The functional continuity plans and site operating plans for extreme events have significantly improved the reliability of our service during some extreme events	The benefits of these plans have resulted in a reduction in the outage levels during some of these extreme events	Yes
	Sea -level rise	Direct flooding	Variable depending on site	Sea-level rise will cause increased flooding	Temporary loss of supply	Analysis of risk for each site, contingency plans for provision of bottled water	Business as usual to deal with existing threat	Individual site risk assessments have been carried out	No sites have been identified that will suffer from flooding as a result of sea level rise	No actions required	Yes

Table 16. Wastewater collection and surface water management											
Business function	**Climate variable (eg increase in temperature)**	**Primary impact of climate variable (eg health)**	**Threshold(s) above which this will affect your organisation**	**Likelihood of threshold(s) being exceeded in the future and confidence in the assessment**	**Potential impacts on organisation and stakeholders**	**Proposed action to mitigate impact**	**Timescale over which risks are expected to materialise and action is planned**	**Progress on implementation of actions**	**Assessment of extent to which actions have mitigated risk**	**Benefits / challenges experienced**	**Future action?**
Wastewater collection and surface water management	Increase in temperature	Demographic change or increased demand for water	Drainage area planning has to be flexible and adaptive to any change (whether resulting from climate change or other causes)	Flood risk is constantly under review, regardless of climate change impact	Flood alleviation and mitigation schemes	Covered by Drainage Area Plans (DAPs)	Flood alleviation schemes are under continuous review, and are primarily dealt with through the Periodic Price Review process	The Universal Metering Programme is causing a reduction in water consumption in areas supplied by Southern Water	The Universal Metering Programme will subdue or delay any potential increase in usage due to increased temperature	Estimated benefits from metering are 16%, which is 6% greater than estimated in the WRMP	Yes
		Increased microbial action and consequent increase from H_2S attack	Unknown	Unknown	Increased costs to deal with issue	Continuous monitoring of water quality (business as usual)	No known timescale – reactive response	Ongoing	Ongoing	Risk avoidance improved	Yes
		Increased wetting and drying cycles, and consequent ground movement	Unknown	Unknown	Increased infiltration and structural failure and increased costs to deal with issue	Periodic monitoring of at-risk sites	Structural condition of sewers is under continuous review and is primarily dealt with through the Periodic Price Review process	In areas prone to high groundwater levels, we have undertaken extensive sealing of sewers to reduce levels of infiltration	Significant reduction in infiltration has been observed in those areas sealed, which has reduced the potential for customer impact at periods of high groundwater levels	Level of mitigation activities required has been significantly reduced, as demonstrated by groundwater levels being significantly higher in 2014-15 than previous years before mitigation was required	Yes
	Less rainfall	Increased water usage	Drainage area planning has to be flexible and adaptive to any change (whether resulting from climate change or other causes)	Flood risk is constantly under review, regardless of climate change impact	Flood alleviation and mitigation schemes	Covered by Drainage Area Plans	Flood alleviation schemes are under continuous review and are primarily dealt with through the Periodic Price Review process	The Universal Metering Programme is causing a reduction in water consumption in areas supplied by Southern Water	The metering programme will subdue or delay any potential increase in usage due to reduced rainfall	Estimated benefits from metering are 16%, which is 6% greater than estimated in the WRMP	Yes
		Longer dry periods and potential for increased blockage rates in sewers	Unknown	Unknown	Increased costs of blockage clearance	Blockages are dealt with immediately	Reactive response	Continuous 'hot spot' analysis identifies areas prone to blockage and allows focused interventions to prevent reoccurrence	Reduced blockages across the drainage network	Ongoing benefits in terms of service provision and interruptions	Yes

Table 16. Water collection and surface water management - continued											
Business function	**Climate variable (eg increase in temperature)**	**Primary impact of climate variable (eg health)**	**Threshold(s) above which this will affect your organisation**	**Likelihood of threshold(s) being exceeded in the future and confidence in the assessment**	**Potential impacts on organisation and stakeholders**	**Proposed action to mitigate impact**	**Timescale over which risks are expected to materialise and action is planned**	**Progress on implementation of actions**	**Assessment of extent to which actions have mitigated risk**	**Benefits / challenges experienced**	**Future action?**
Wastewater collection and surface water management	Increased storminess	Direct flooding of property and company assets	Variable depending on site	Increased storminess will cause increased flooding	Increased flooding	Covered by Drainage Area Plans. From July 2015 review design criteria in light of new information from Convex Model Project and UKWIR CL10A205	Flood alleviation schemes are under continuous review, and are primarily dealt with through the Periodic Price Review process	Sewer design criteria now has a 20% uplift in peak rainfall to allow for climate change and 300mm freeboard on above ground flood protection is provided in schemes	New or replacement sewers and flood protection measures have sufficient capacity to accommodate realistic climate change scenarios	Negates the need to address climate change on these sewers as separate interventions and future proofs current interventions	Yes
		Loss of power supply	Immediate impact	Dependent on third party suppliers	Temporary loss of collection system	Analysis of risk for each site, contingency plans for dealing with flooding, on-site generation for high-risk sites	Business as usual to deal with existing threat	Assessment of back-up power supplies at our strategic sites has been carried out and mobile hook up connections have been made available	Risks have been reduced at each site via the contingency planning process	This has resulted in robust contingency planning that is adhered to in the event of power supply loss	Yes
		Logistic and transport difficulties	Variable depending on site	Increased storminess will cause increased flooding	Temporary loss of collection system	Analysis of risk for each site, contingency plans for dealing with flooding, on-site generation for high-risk sites	Business as usual to deal with existing threat	Functional continuity plans have been derived for all operational areas to enhance resilience	The functional continuity plans and site operating plans for extreme events have significantly improved the reliability of our service during some extreme events	The benefits of these plans have resulted in a reduction in the outage levels during some of these extreme events	Yes
		Higher groundwater table	Variable depending on site	Sea-level rise will cause increased flooding	Increased infiltration and increased costs to deal with additional flow	Covered by Drainage Area Plans	Business as usual to deal with existing threat	Development of prioritised and targeted infiltration reduction plans to reduce/manage infiltration	Where IRP actions have been implemented, appreciable gains have been achieved to reduce infiltration	Opportunities for partnership working and an holistic approach to managing flooding	Yes
	Sea -level rise	Direct flooding of property and company assets	Variable depending on site	Sea-level rise will cause increased flooding	Increased flooding	Covered by Drainage Area Plans	Flood alleviation schemes are under continuous review, and are primarily dealt with through the Periodic Price Review process	Initial desktop review of sites using flood risk maps, then detailed site investigations and investment proposals developed and prioritised based on threat level	Where DAPs have been updated and utilised, appreciable gains have been achieved to reduce flooding	Undertaking the review not only identifies the sites at risk of flooding but also allows prioritisation based on threat level	Yes
		Increased sea level preventing free discharge of surface water	Variable depending on site	Sea-level rise will cause increased flooding	Increased flooding or need for more pumping stations	Covered by Drainage Area Plans	Flood alleviation schemes are under continuous review, and are primarily dealt with through the Periodic Price Review process	Ongoing work with Lead Local Flood Authorities and other risk management authorities on the development of Surface Water Management Plans, prioritised on flood risk	Where DAPs have been updated and utilised, appreciable gains have been achieved to enhance resilience and reduce flooding	Undertaking the review not only identifies the sites at risk of flooding but also allows prioritisation based on threat level	Yes

Table 17. Wastewater treatment											
Business function	**Climate variable (eg increase in temperature)**	**Primary impact of climate variable (eg health)**	**Threshold(s) above which this will affect your organisation**	**Likelihood of threshold(s) being exceeded in the future and confidence in the assessment**	**Potential impacts on organisation and stakeholders**	**Proposed action to mitigate impact**	**Timescale over which risks are expected to materialise and action is planned**	**Progress on implementation of actions**	**Assessment of extent to which actions have mitigated risk**	**Benefits / challenges experienced**	**Future action?**
Wastewater treatment	Increase in temperature	Demographic change or increased usage of water	Wastewater treatment planning has to be flexible and adaptive to any change (whether resulting from climate change or other causes)	The effluent quality from treatment works is constantly under review, regardless of climate change impact	Increased treatment capacity required	Periodic review of available treatment capacity	Requirement for additional capacity addressed through Periodic Price Review process	Assessed treatment works to understand capacity and performance constraints in the near and long term	Identified and financed for incremental process improvements	Yet to be fully realised	Yes
		Increased microbial action	Unknown	Unknown	Increased costs to deal with issue, or may provide benefits to treatment process	Continuous monitoring of wastewater effluent quality (business as usual)	No known timescale – reactive response	Regularly trending of performance of treatment works	Ongoing	Risk avoidance improved	Yes
		Potential increased impact on receiving water (lower river flows)	The effluent quality from treatment works is constantly under review, regardless of climate change impact	Potentially tighter discharge standards to protect environment	Environmental permits are the responsibility of the Environment Agency	Requirement for tighter standards addressed through Periodic Price Review process	The effluent quality from treatment works is constantly under review, regardless of climate change impact	PR14 Business Plan developed to meet Environment Agency National Environment Programme requirements	Ongoing	Yet to be fully realised	Yes
		Increased wetting and drying cycles and consequent ground movement	Unknown	Unknown	Increased costs to deal with issue	Periodic review of structural condition of assets	No known timescale – reactive response	Risks are identified on our asset risk inventory	ARM risks are prioritised and implemented in a timely manner to avoid catastrophic failure	Improved risk reduction	Yes
	Less rainfall	Increased water usage	Wastewater treatment planning has to be flexible and adaptive to any change (whether resulting from climate change or other causes).	The effluent quality from treatment works is constantly under review, regardless of climate change impact	Increased treatment capacity required	Periodic review of available treatment capacity	Requirement for additional capacity addressed through Periodic Price Review process	We have aligned per capita consumption assumptions used in WRMP (including climate change) and efficiency with growth forecasts used for wastewater investment planning	Our investment plans include for managing growth, implemented when need/certainty is confirmed	Universal Metering Programme has realised 16% reduction in household consumption thus far, with follow-on impact to wastewater treatment	Yes

Table 17. Wastewater treatment – continued											
Business function	**Climate variable (eg increase in temperature)**	**Primary impact of climate variable (eg health)**	**Threshold(s) above which this will affect your organisation**	**Likelihood of threshold(s) being exceeded in the future and confidence in the assessment**	**Potential impacts on organisation and stakeholders**	**Proposed action to mitigate impact**	**Timescale over which risks are expected to materialise and action is planned**	**Progress on implementation of actions**	**Assessment of extent to which actions have mitigated risk**	**Benefits / challenges experienced**	**Future action?**
Wastewater treatment	Increased storminess	Direct flooding of treatment sites	Variable depending on site	Increased storminess will cause increased flooding	Temporary loss of treatment facilities	Analysis of risk for each site, contingency plans	Business as usual to deal with existing threat	Completed AMP5 resilience assessments and reviewed risk of flooding as part of PR14 business planning process	Greater understanding of risks and PR14 cost benefit assessment undertaken for each mitigation scheme	Improved risk reduction and preparedness	Yes
		Loss of power supply	Immediate impact	Dependent on third party suppliers	Temporary loss of treatment facilities	Analysis of risk for each site, contingency plans, on-site generation for high-risk sites	Business as usual to deal with existing threat	Assessment of back up power supplies at our strategic sites has been carried out and mobile hook up connections have been made available	Risks have been reduced at each site via the contingency planning process	This has resulted in robust contingency planning that is adhered to in the event of power supply loss	Yes
		Logistic and transport difficulties	Variable depending on site	Increased storminess will cause increased flooding	Temporary loss of treatment facilities	Analysis of risk for each site, contingency plans	Business as usual to deal with existing threat	Functional continuity plans have been derived for all operational areas	The functional continuity plans and site operating plans for extreme events have significantly improved the reliability of our service during some extreme events	The benefits of these plans have resulted in a reduction in the outage levels during some of these extreme events	Yes
	Sea-level rise	Higher groundwater table, potential increase in saline intrusion	Variable depending on site	Sea-level rise will cause increased saline intrusion	Increased costs to deal with issue (additional treatment requirements)	Continuous monitoring of effluent quality	Dependent on rate of sea level rise	Development of prioritised and targeted infiltration reduction plans (IRPs) to reduce/manage infiltration	Where IRPs have been introduced, appreciable gains have been achieved to reduce infiltration	Opportunities for partnership working and an holistic approach to managing flooding	Yes
		Direct flooding of treatment sites	Variable depending on site	Increased storminess will cause increased flooding	Temporary loss of treatment facilities	Analysis of risk for each site, contingency plans	Business as usual to deal with existing threat	Functional continuity plans have been derived for all operational areas	The functional continuity plans and site operating plans for extreme events have significantly improved the reliability of our service during some extreme events	The benefits of these plans have resulted in a reduction in the outage levels during some of these extreme events	Yes

Table 18. Sludge recycling											
Business function	**Climate variable (eg increase in temperature)**	**Primary impact of climate variable (eg health)**	**Threshold(s) above which this will affect your organisation**	**Likelihood of threshold(s) being exceeded in the future and confidence in the assessment**	**Potential impacts on organisation and stakeholders**	**Proposed action to mitigate impact**	**Timescale over which risks are expected to materialise and action is planned**	**Progress on implementation of actions**	**Assessment of extent to which actions have mitigated risk**	**Benefits / challenges experienced**	**Future action?**
Sludge recycling	**Increase in temperature**	Increased odour or septicity	Unknown	Unknown	Increased costs to deal with issue	Monitoring of complaints	No known timescale – reactive response	Ongoing	Ongoing	Unknown at this stage	Yes
		Change in crop types which may not require biosolids application	Unknown	Unknown	Increased costs to deal with issue	Periodic review of options for sludge recycling	No known timescale – reactive response	Review of sludge strategy early in AMP6 will include the predicted impact of externalities on our land bank	Revised strategy will look more long term at the opportunities and challenges that exist	Yet to be fully understood	Yes
	Less rainfall	May increase demand for biosolids to improve dry soil	Unknown	Unknown	Beneficial impact on recycling options	Periodic review of options for sludge recycling	No known timescale – reactive response	Treated sludge is often used as a soil conditioner	No trend identified that can be separately attributed to climate change	Unknown at this stage	Yes
	Increased storminess	Increased risk of spoilage of sludge stockpiles	Variable depending on site	Unknown	Increased costs to deal with issue	Periodic review of options for sludge storage	No known timescale – reactive response	Currently treat, produce and dispose a compliant product 100% of the time	Ongoing	None identified	Yes
		Logistic and transport difficulties	Variable depending on site	Increased storminess will cause increased flooding	Increased costs to deal with issue	Periodic review of options for sludge recycling	No known timescale – reactive response	Contingency plans exist to manage the risk of a site or sites being unavailable temporarily	No trend identified that can be separately attributed to climate change	Unknown at this stage	Yes

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