Water resources long-term planning framework

(2015-2065)

Summary Report

WATER UK

Foreword

Providing safe, clean water is at the heart of what water companies do. Since privatisation, the industry has invested billions of pounds in securing the nation’s precious water resources. However, as this detailed report suggests, mains water cannot be guaranteed even today, and this is a problem that will become more severe.

Earlier this year, the government challenged the industry to understand more fully the future challenges and solutions in terms of our resilience to the risk of drought. The industry has enthusiastically responded with what we believe to be the fullest study of national water resource availability and pressures ever undertaken in this country.

This work, by independent consultants and peer reviewed by a panel of leading experts, has found that the problem is even more pronounced than had been thought. If we carry on with ‘business as usual’, droughts are likely to become both more frequent and more geographically widespread than previously understood.

The water industry is committed to continue playing its full part in addressing these challenges, but it cannot solve the problem alone. We will have to work in close partnership with customers, government, regulators, the National Infrastructure Commission, and with our partners throughout the sector.

We will also need every tool in the box. We will need more efficient use of water at home, in business and in agriculture. We will need to reduce leakage further. We will need a new approach to sharing water across regions, bearing in mind that increasing resilience in one area may affect the level of resilience in another. We will need new sources of supply and new storage. We will need tried and tested techniques, and new and emerging technologies such as smart meters.

Customers, as always, need to be at the heart of our response. The industry is exploring how best to engage customers on long-term issues, such as resilience. While the scale of ambition will be considerable, increasing resilience in this way should not require unaffordable changes in bills if we take this work forward on a collective and timely basis. Water can remain affordable for customers and rightly so, given that it is essential to life.

Ultimately, how we respond to the prospect of more frequent and more severe water shortages depends on the country’s appetite for risk. As that prospect cannot be eliminated entirely, it is important for government to establish what is acceptable in terms of levels of resilience to drought, thereby informing the policy, planning, regulatory and implementation priorities for the water sector. We hope this report will help shape that debate and the actions which flow from it.

Michael Roberts
Chief Executive, Water UK

Jean Spencer
Regulation Director, Anglian Water &
Long Term Water Resources Project Chair

Contents

Introduction

Customers' top priority for water services is a safe, reliable supply of water at a price they can afford. To deliver this, it is critically important that the water industry plan for the long term because decisions and investments made today will determine the level of service that the industry can provide well into the future.

Water customers already face the risk of drought. Over the last 40 years there have been a number of droughts that were worse than those that had been used as the basis of planning. These droughts had significant impacts on customers and the environment: in 1976 customers were subject to severe restrictions, including standpipes; in 1995-96, supplies to customers in Halifax and Bradford were only maintained by 600 tankers every day moving water from Kielder to Yorkshire; and in 2012, two dry winters caused conditions in April worse than any historic drought for the South and East and the situation only recovered as there was

an exceptionally wet summer – the wettest on record. Drought events in the future may be different to historic droughts which form the basis for Water Resource Plans at the moment. Without intervention, the risk of experiencing drought impacts may get worse.

Under the Water Act 2014, both the Secretary of State and Ofwat have a duty to further the 'resilience objective' in England and Wales. Ofwat's Resilience Task and Finish Group defined resilience as:

> *"The ability to cope with, and recover from, disruption, and anticipate trends and variability in order to maintain services for people and protect the natural environment now and in the future."*

Water companies are already required to plan to secure the resilience of their operations to incidents such as floods and fire, and to drought. Increasing pressures on water resources, from factors such as climate change, population growth and the need to reduce abstractions to protect the aquatic environment, call for an increased focus on the drought-resilience of our water supply systems.

This is the first study to look at the picture for public water supply in England and Wales and consider the combined impacts of the challenges of climate change, population growth and the need to reduce abstractions to protect the environment. It takes a longer term (50 years) perspective than current water resource management plans and develops new modelling of droughts, climate change impacts, and the resilience of supplies. It assesses England and Wales' long-term water needs and the options available for meeting them.

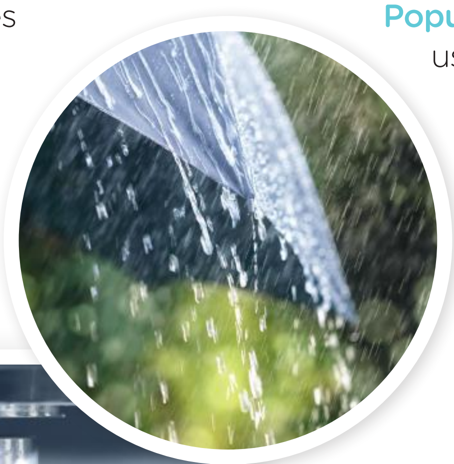
The study was funded by Water UK, led by a steering group comprised of water companies, regulators and UK and Welsh government representatives. The work was carried out by a consortium comprised of Atkins, Mott Macdonald, NERA Economic Consulting, HR Wallingford and the Environmental Change Institute (based at Oxford University). It was reviewed by an independent panel: Professor Jim Hall (University of Oxford and member of the Committee on Climate Change Adaptation), Dr Colin Fenn (Hydro-Logic Solutions), Robin Smale (Vivid Economics) and Dr Steven Wade (Met Office).

A summary of the project scope, findings, conclusions and recommendations are set out in this report with further details in the full report and technical annexes.

Key messages and recommendations

There is a significant and growing risk of severe drought[1] impacts arising from climate change, population growth and environmental drivers.

Climate change. Hotter temperatures will drive up demand for water, as well as increasing evaporation during spring and summer. The impact of climate change on rainfall is uncertain – but the possibility of prolonged dry periods cannot be excluded. Drier climate futures would markedly increase drought risk, even at the 2040 horizon. While water resources in some areas are resilient to climate change, others are expected to experience a significant impact on water availability. For example, a dry climate could treble the risk of experiencing a severe drought in the East of England. The Committee on Climate Change's Adaptation Sub-Committee 'UK Climate Change Risk Assessment Evidence Report' gives risk of shortages in water supply as a priority area where more action is needed.



Population growth. The scenarios used indicate population growth for England and Wales of between 6.6 million and 16 million by 2040, and between 13 million and 33 million by 2065. The least resilient and most water stressed areas in the South and East are also subject to most growth and climate change risk.

Preserving water for the aquatic environment. The UK is home to globally important wetlands, rivers and chalk streams, which are valued by water customers and rely on water availability. A resilient natural environment also forms the basis for sustainable water supplies. Therefore, it is in the national interest to conserve water for the environment. The abstraction of water will need to be reduced to restore this natural resilience. Restrictions on abstractions will be felt by users of water for agriculture, power and industry, as well as public water supplies. The impacts are felt most by the areas served by five companies: Affinity, Anglian, Severn Trent, Southern and Thames. For those companies, it may be necessary to reduce the amount of water currently available for abstraction by between 5% and 50%.

There is a strong case for the UK and Welsh governments to consider adopting consistent national minimum levels of resilience, recognising that there are significant issues to address, including inter-regional and inter-generational fairness.

Society faces choices about its risk appetite for severe restrictions on water use during major drought events. These risks cannot be entirely eliminated. Companies' customer engagement needs to explore the inter-generational and national aspects of decisions made at a company scale. Companies' level of resilience is a matter of public interest and public policy as well. For example, the availability of water to agriculture depends upon the resilience of public water supply, which takes precedence in times of water stress.

The investment needed to increase resilience is relatively modest compared with the cost of drought.

In most areas the additional costs of becoming resilient to 'severe' drought events are less than £4 per household-customer per year[2], if the right measures are taken early enough. Bill impacts would not be immediate: they will take effect gradually as investment in demand reduction and supply options are delivered. The 'central estimate' of the benefit, that is, of the value customers place on avoiding severe restrictions, is ten times more than this cost, and is still four times greater than the cost even if low case estimates of the benefits are assumed.

A 'twin track' approach that includes supply enhancement, with associated transfers, as well as demand management, is the most appropriate strategic mix for the future.

There is a case for considering more extensive measures to manage demand than today, both to give a greater level of resilience to more extreme future shocks than those considered within this report and to reduce the risk of regretted investment in infrastructure if more favourable futures materialise. Demand management includes measures to reduce household and business consumption and to reduce leakage. The levels of demand management considered in this report are potentially ambitious, relying on significant behavioural change and significant future innovation to make the options more feasible economically. Inter-regional transfers and new storage capacity may represent key components of a more resilient system, through a combination of localised initiatives and strategic schemes that use the River Severn and River Trent to carry water across to the South and East. Connecting major supply systems has implications for river regulation, water quality, environmental risk and, in some cases, the nature of drought risk within the supplying water resources systems.

Key messages and recommendations

There is a case for a national level ‘adaptive plan’ that supports ongoing Water Resource Management Plans (WRMPs) and balances risks against opportunities to defer costs.
Such a plan would identify the key ‘trigger points’ that will determine which set of investments and policy interventions would be needed for the 2040 and 2065 horizons, depending on how risks materialise in the future. Some risks are immediate and need a prompt response: the risk of drought is present now and the government aims to achieve sustainable levels of abstraction by the 2020s. We are already facing the effects of a hotter climate. The impact of population growth is uncertain and will play out over a longer time. The most cost-effective approaches to increasing resilience involve action in the current round of Water Resource Management Plans to avoid having to rely on more expensive options later on.

Industry, government and regulators need to work together with customers on how best to respond to the risk of severe drought.
Companies will need to develop new ways of working across their boundaries and with a wider range of stakeholders to optimise the use of scarce water resources, particularly through transfers. The findings of this report add weight to the already-recognised need for companies to deepen their engagement with customers. Companies need to work with housing developers to increase the water efficiency of new homes. There is a role for a supportive government policy and regulatory framework.

This report provides a significant new evidence base which should provide valuable evidence to the National Infrastructure Commission’s first National Infrastructure Assessment and any National Policy Statement on Water Resources.[3]

This report provides a first, high-level assessment. Further work will be needed to test the assumptions and methods used.
Water companies’ water resource management plans will need to verify the results, develop detailed plans that align with customers’ wants and confirm the best value water infrastructure development plans. Inter-company planning forums such as Water Resources East (WRE) and Water Resources South East (WRSE) can conduct cross-company and stakeholder initiatives to better understand the risks involved, and the commercial/institutional arrangements required to support future transfers. There may be the need for enabling actions that can increase the scope of these forums so that they can encompass larger national-scale developments.

1 A ‘severe’ drought is one that is worse than those experienced in the 20th century, which might only be expected to occur once every couple of centuries, but could cause several months’ worth of emergency drought restrictions under current levels of planned drought resilience.

2 Figure based on the difference in the total cost of developing systems to manage future risk at the different levels of resilience; uses annualised costs over the 50-year period of analysis.

3 As anticipated in ‘Creating a great place for living: Enabling resilience in the water sector’. Defra 2016

Project scope and approach

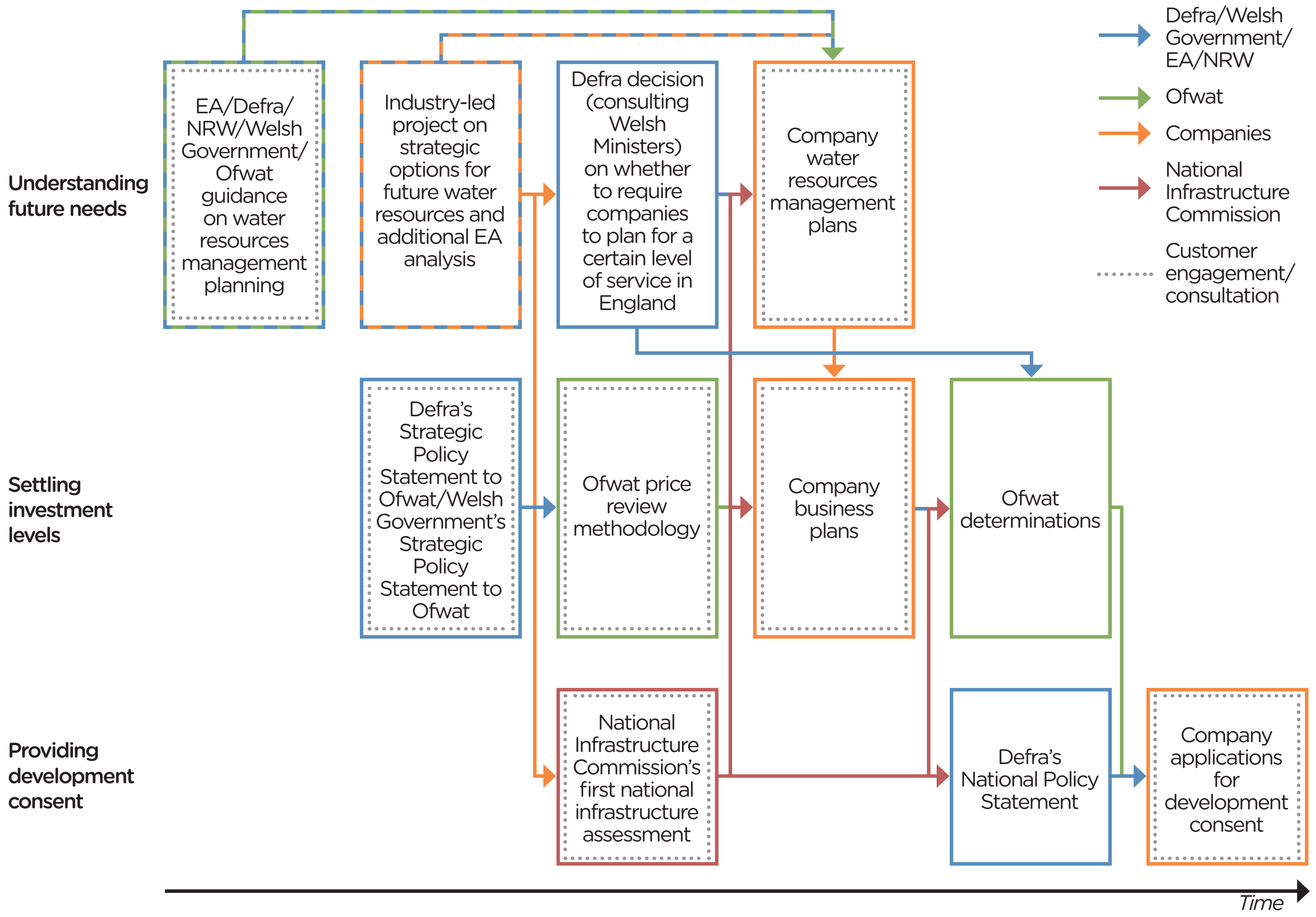
The primary aim of the project is to develop a high-level strategy and framework for the long-term planning of water resources for public supply in England and Wales.
It considers:

- A sector-wide view of future resilience and options for improving that resilience; and
- An assessment of variation in levels of service and potential minimum levels of service for customers and the environment, accounting for costs and benefits at a national, regional and sub-regional level, which includes the wider social impacts of drought and drought resilience.

The analysis includes:

- An assessment of the scale of the potential impacts of climate change, population growth and reductions in abstractions to protect the aquatic environment;
- The scale of deficits in 2040 and 2065 for each region across a range of futures;
- High-level portfolios of options that could be used to address the range of possible futures and identifies those options that are most drought-resilient and cost-effective;
- Consideration of the societal and economic costs of water supply failures and the costs and benefits of investing to avoid such failures.

The evidence and framework developed through this project aims to inform the development of national policy and infrastructure needs assessment, water companies’ Water Resource Managament Plans and Business Plans for the next Price Review in 2019:

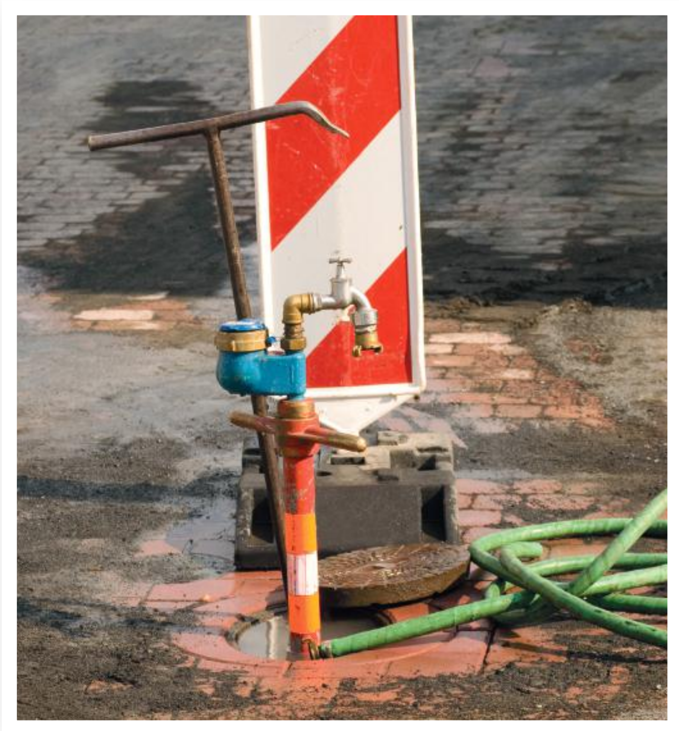


What happens in a drought?

In a succession of dry years, or when the risks of drought become significant, measures to reduce demand help remaining water to last longer. Droughts have potentially very large consequences that depend on the severity and duration of the restrictions placed on water use.

The first level of restriction includes Temporary Use Bans (TUBs), formerly known as hosepipe bans, mostly limiting household water uses. This would be followed by Ordinary Drought Order or Non-Essential Use bans (ODOs, NEUs), mostly affecting business water uses.

In more severe droughts, Emergency Drought Orders may be required. These allow increased abstraction for Public Water Supply outside that permitted by an abstraction licence, restrict abstraction by other users, such as agriculture, and restrict public water supplies to customers much more severely through a mix of rota-cuts and standpipes, with water then available from bowsers or bottled water supplies. However, these interventions have not been tested at scale and a question remains over whether there would be adequate facilities in a widespread severe drought. In emergencies, bulk imports of water by tanker might be



considered, although, again, the adequacy of tanker provision is untested.

These drought restrictions either have a direct effect on customers (e.g. restrictions on their use) or on the environment (e.g. more water taken from rivers). A balance needs to be struck between the consequences of restrictions for people and the environment and the costs of avoiding the restrictions by investing in additional supply or demand measures.

Severity	Households	Non-households		
	PWS supplies	PWS supplies	private abstraction	spray irrigation
Level 1	Media campaigns and communications			
Level 2	Temporary Use Bans	TUB (for the few affected non-household activities)	Hands off Flow limits apply	Partial restriction
Level 3	Temporary Use Bans	Ordinary Drought Order (demand-side)	Ordinary Drought Order (demand-side)	Full restriction
Level 4	Emergency Drought Order	Emergency Drought Order	Ordinary Drought Order (demand-side)	Full restriction

This project is focused on assessing the consequences of the most severe, Level 4, restrictions: those that would apply when an Emergency Drought Order was in place.

Customers place a high value on avoiding severe restrictions such as rota-cuts or standpipes, in the range £40-£160 to avoid one day of interruption to household supplies. Economic losses from restrictions on business and public sector water users are additional: for England and Wales as a whole, estimates suggest a 37%[4] loss of non-household Gross Value Added (GVA) at times when the most severe level of restrictions affect all non-households; applied across both countries that would be an economic loss of approximately £1.3 billion[5] per day; this figure needs to be scaled down to match the GVA of the region affected by drought restrictions.

4 Within a wide plausible range of 20% to 60%.

5 Applying the 37% central figure to the 2013 GVA level (approximately £3.5 billion per day for England and Wales) suggests that severe restrictions across the whole of both nations would cause GVA loss of £1.3 billion per day.

Findings and conclusions

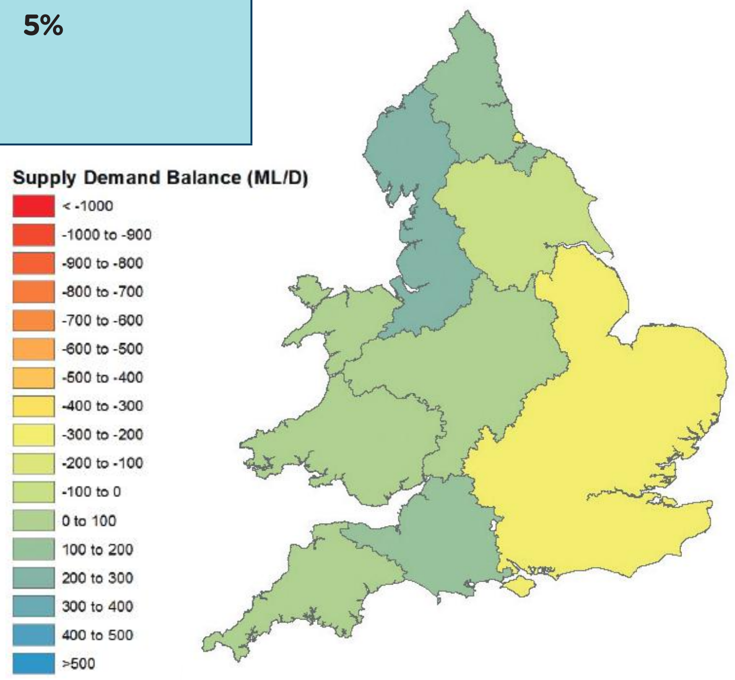
1: Existing drought risk *(see Section 6.1 for the evidence base)*	**There is a significant and increasing risk of severe drought across many regions in the South and East of England.** Putting this in context, those companies whose Water Resource Management Plan anticipates no deficit or surplus against planning standards, and being resilient to the worst historic drought on record, still run a 12% chance of seeing a drought event with standpipes or similar in place for 2 to 3 months over a 25-year planning period. There is a lesser risk (circa 5% in 25 years) that such an event could turn into an 'extreme' drought with drought restrictions lasting for 4 to 6 months.

Risks of droughts have been considered at three levels based on Drought Deficit Regions

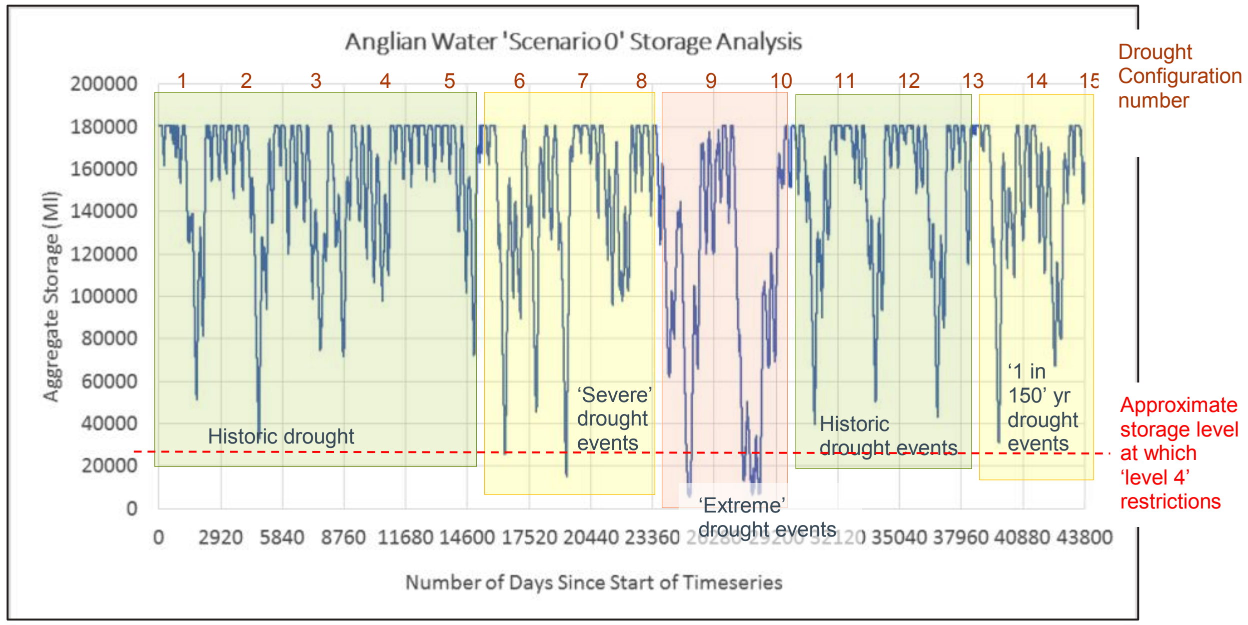
Drought Severity Level	Description	Probability that a drought at or worse than that level of severity would be experienced in a 25-year planning period
Worst historic	Significant events with a severity equal to the worst events seen in the 20th century record	**22%**
Severe	Rare events beyond those seen in the 20th century – might only be expected to occur once every couple of centuries	**12%**
Extreme	Very rare events of a type only observed a few times in the even longest reconstructed records (using tree ring analysis or similar)	**5%**

The map shows the supply demand balance in each region for a combination of resilience to historic drought, baseline climate change, baseline abstraction reductions, medium population growth and business as usual 'base' demand management.

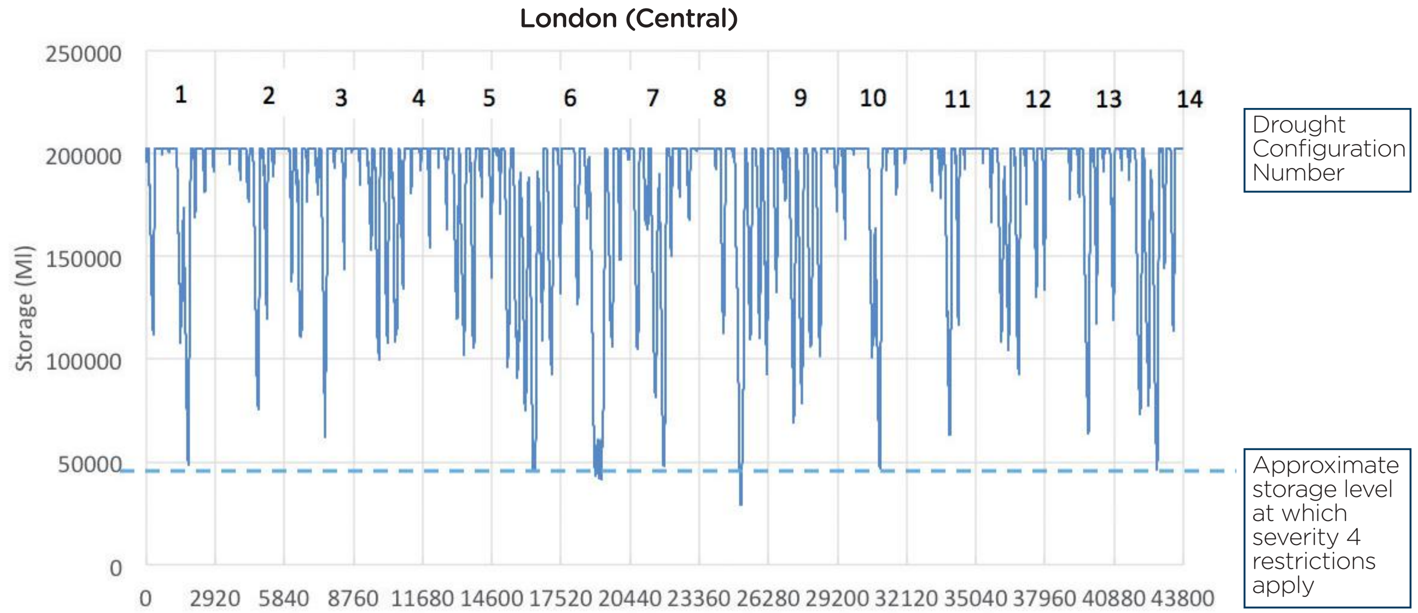
See Fig 6-27 in the main report.



The analysis assessed the resilience of water supplies to 15 drought scenarios (five historic and ten modelled droughts): the charts below illustrate, for the Anglian and Thames-London regions, that in many of these drought scenarios the levels of storage fall to a level where the most severe level 4 restrictions, including standpipes, would be required.



This figure shows the storage levels reached during each year of the Drought Configuration timeseries for the Anglian Water reservoirs (blue line). Each drought sequence contains a drought ranging from low severity for this particular system (e.g. 1996 in the green area), to 'extreme' droughts (contained in the red area). Each separate Drought Configuration timeseries lasts for 8 years, which is represented by a single box width in the diagram.



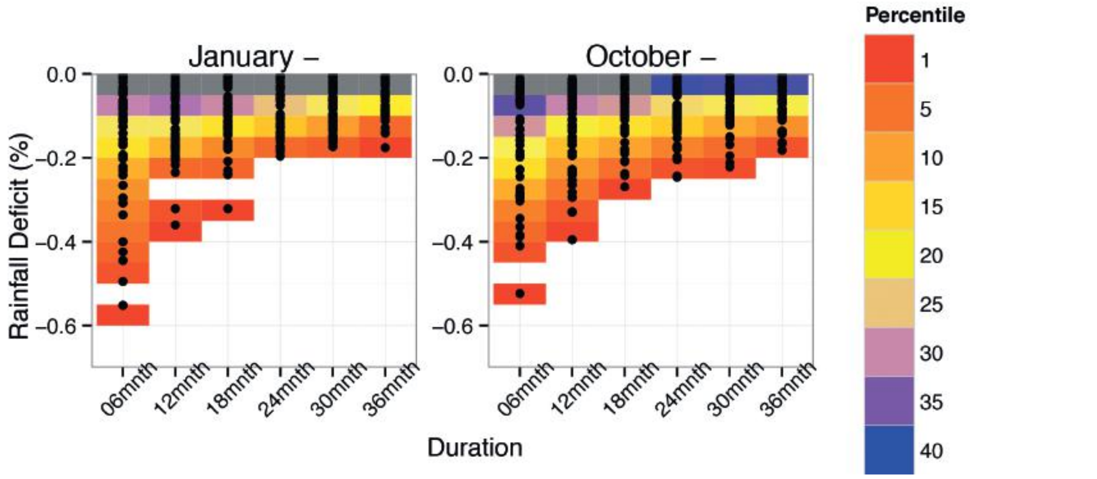
2: Reliability of drought orders/ permits	While Drought Orders and Permits are an essential instrument for drought management, it is not certain how much they can be relied upon both now and in the future.
(See Section 6.1.2 for the evidence base)	Drought Orders and Permits that allow increased abstraction potentially make an important contribution to alleviating the impacts on public water supplies of 'severe' and 'extreme' droughts. Although links between Drought Plans and WRMPs are starting to be made for planning purposes (see latest Water Resources Planning Guidelines), there is uncertainty surrounding the 'reliability' of such operational supply side interventions as a means for mitigating drought risk and deferring investment in resilience given the current links between investment planning (WRMPs) and operational drought planning (Drought Plans). Aspects of Permits and Orders such as the lead times required for preparation, application and potential public hearings prior to implementation are not currently well enough defined to incorporate them into investment plan analysis in a reliable way. Additionally, environmental concerns mean that companies are often limited to winter Permits/Orders, or have to introduce mitigation that could severely limit the benefits of the actions. Supply-side Drought Permits/Orders are by their very nature contentious because of the potential environmental impacts at times of drought stress. If a policy decision is made to plan for a higher level of drought resilience than is currently planned for within WRMPs (i.e. worst historic in most cases), then there will be a need for water companies and stakeholders to agree on the methods that can be used to determine the reliability of Permits and Orders as a means of providing resilience or to prioritise investment.

The study has highlighted the importance of understanding the reliability of Permits and Orders in relation to resilience investment and planning.

The analysis allowed for the application of orders and permits using the following assumptions.

Environmental Risk & Company Experience	Drought Timeline		
	< 12 months	12-24 months	25+ months
Low/Good (400Ml/d)	50% @ DP	100% @ DP	100% @ DP
Moderate/Limited (350Ml/d)	None	50% @ DP	100% @ DP
Poor/None (108 No.)	None	None	None

Historic data and modelled analysis indicates that all significant droughts involve a period of intense deficit during the critical period. This means there will always be a relatively limited notice for Permits and Orders.



Example of a rainfall deficit-duration plot: This figure shows how the deficit in rainfall (Y axis), expressed as a proportion of the long-term average (i.e. -0.6 = 60% reduction compared with the long-term average), reduces as the length of the deficit period (drought) increases (x axis). See Fig 6-1 in the main report.

3: Climate change risks	Impacts of climate change on drought risks are uncertain but could be happening already, meaning that drought risks are increasing.
(see Section 6.4 for the evidence base)	Analysis based on historic droughts does not fully account for climatic variability and droughts that could have occurred in the past (but didn't). Hotter temperatures will drive up demand for water, as well as increasing evaporation during spring and summer. The impact of climate change on rainfall is uncertain – but the possibility of prolonged dry periods cannot be excluded. The country has experienced some 'near misses' such as 2012, and there is currently insufficient information to determine how the risks from climate change are affecting the likely frequency and severity of significant drought events, and further climate change research would be required to provide a system of monitoring/analysis that could provide the required understanding. The Committee on Climate Change's Adaptation Sub-Committee UK Climate Change Risk Assessment Evidence Report gives risk of shortages in water supply as a priority area where more action is needed.

The analysis considered two climate change scenarios: median (a central estimate – the 'baseline' climate scenario in this report) and extended (a drier climate – approximately 75th percentile of the potential range).

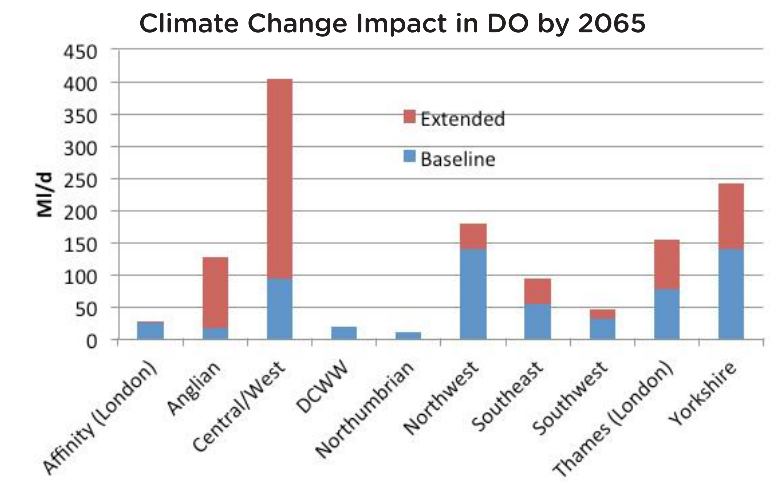
Wetter climates (wetter than the median) were not considered, although the analysis of consequences and cost/benefit ratios of adopting potential future strategies did account for this assumption.

Even under these relatively modest scenarios, the potential impacts of climate change are significant:

- 2040: 7% loss in water available (deployable output) for a severe drought under a median climate change through to a 17% loss for an extreme drought under a dry climate
- 2065: this increases to a range of between 9% and 22% loss of deployable output.

The impacts are highly variable between regions.

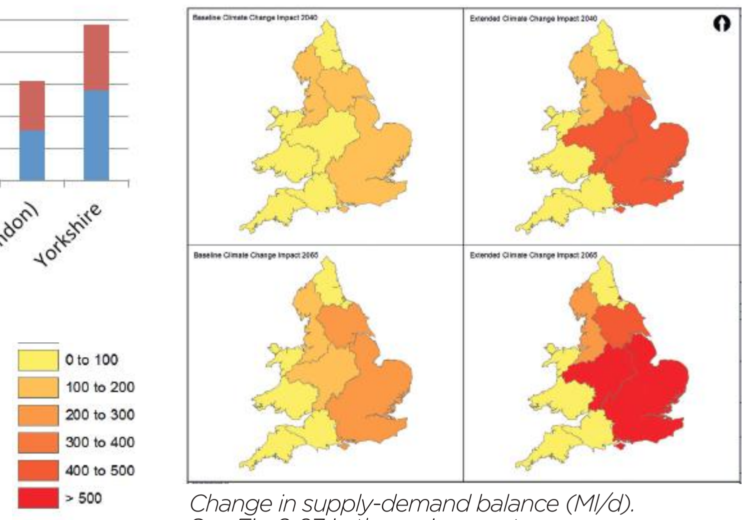
The chart shows the reduction in water available (deployable output) under the two climate change scenarios used (baseline and extended).
See Fig 6-20 in the main report.



Climate change impact on water availability (deployable output) by region – 2040 (top) and 2065 (bottom) under base (left) and extended (right) climate change scenarios.

Under a moderately dry future, the risk of cessation of piped supplies and consequent use of standpipes, tankers etc., (severity level 4, see p.5 in the technical report) could:

- Double, on average, in the South East (excluding London) and Bristol;
- Treble for Thames-London and the Anglian regions.



Change in supply-demand balance (Ml/d). See Fig 6-23 in the main report.

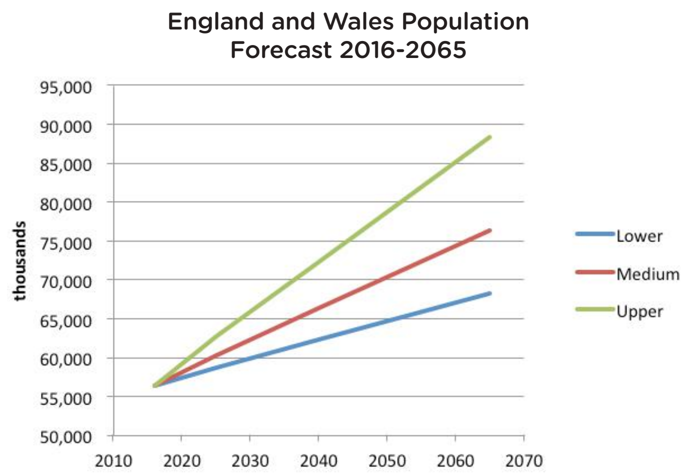
4: Population growth *(see Section 6.3 for the evidence base)*	**The range and pace of population growth is a material uncertainty in planning water resources, but can be monitored and adapted over time.** The Office for National Statistics (ONS) estimates population growth for England and Wales of between 6 and 16 million by 2040 and between 12 and 32 million by 2065.

The analysis was based on three scenarios of growth: lower, medium and upper:

- In lower population growth forecasts, growth is more than offset by savings in demand through business as usual strategies
- Medium population growth is offset by demand savings in the early years
- In upper growth forecasts, population increases outstrip demand management savings.

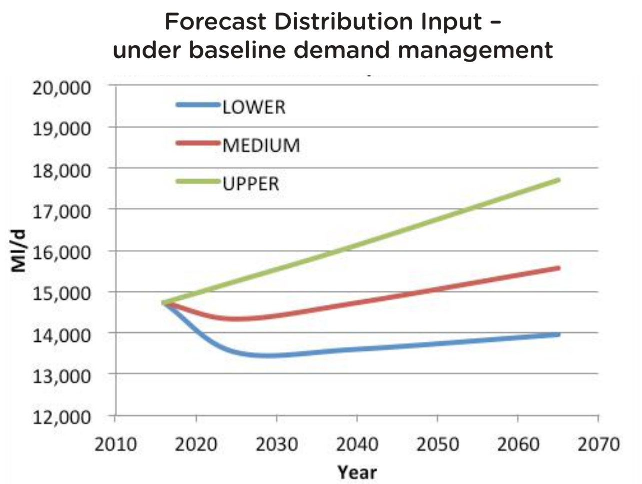
Population forecasts.

See Fig 6-12 in the main report.



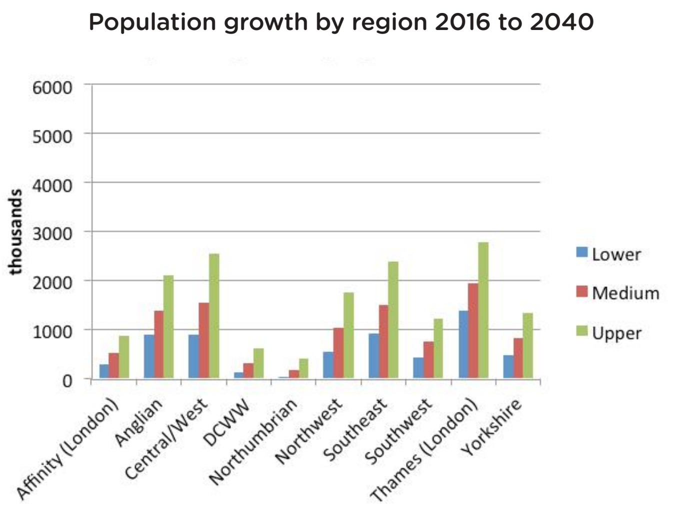
Water supplied (Distribution Input).

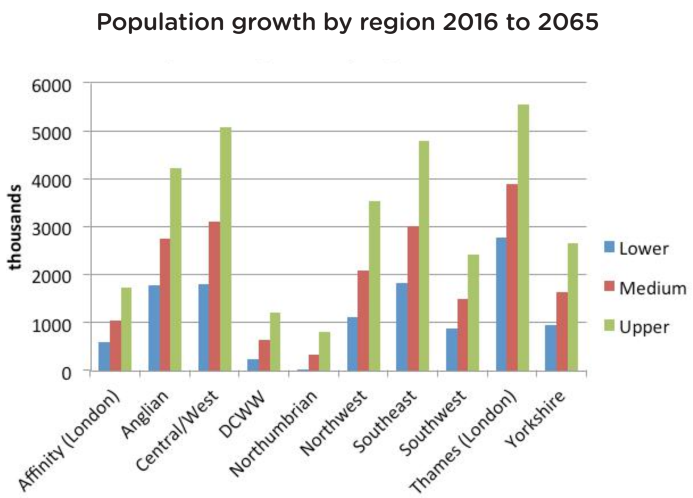
See Fig 6-15 in the main report.



Growth is projected not to be evenly distributed across England and Wales. The largest population growth is projected in London, the South East, East Anglia and Central England, where water resources are already relatively scarce.

See Fig 6-13 and 6-14 in the main report.

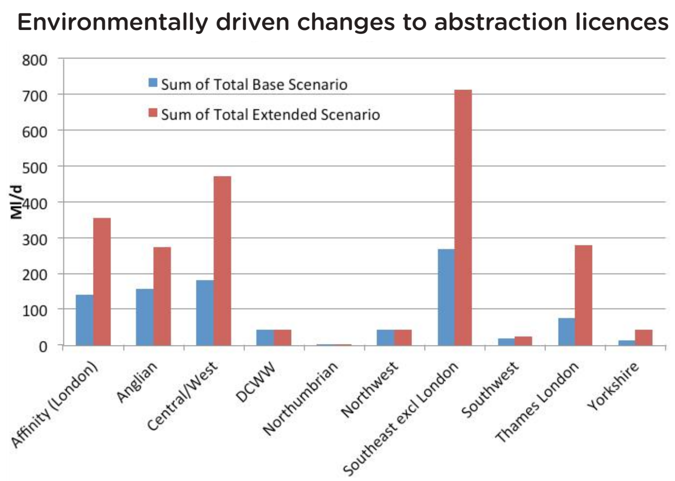




5: Reduction in abstraction licences to protect the aquatic environment *(see Section 6.2 for the evidence base)*	**The impact of reducing abstraction to protect the environment is uncertain, but expected to be very large in some areas. The impacts are felt most by the areas served by five companies: Affinity, Anglian, Severn Trent, Southern and Thames. For those companies, the amount of water currently available could be reduced by between 5% and 50%.** The UK's freshwater natural capital is valuable in its own right and a resilient natural environment is more likely to be able to respond to future challenges. Changes to abstraction and management of water are required to manage our natural environment in a sustainable manner. A range of potential abstraction changes have been signalled by the Environment Agency and Natural Resources Wales. Reductions in abstraction licences to protect the aquatic environment have the potential to have a substantial impact on the supply/demand balance across England and Wales, especially under higher growth scenarios. There is considerable uncertainty over the magnitude of reductions. Reductions may be required in the near future, by 2025, and uncertainty should be resolved as soon as possible if reductions are to be reflected in WRMPs and PR19.

There is considerable uncertainty over the magnitude of impacts on deployable output that will arise from changing abstraction licences in order to meet and preserve good ecological status of water bodies and the habitats they support.

The impacts vary significantly between companies and regions, reflecting the differing nature of abstraction and historic licensing regimes, which are continuously under review, and likely to change further as part of abstraction reform.

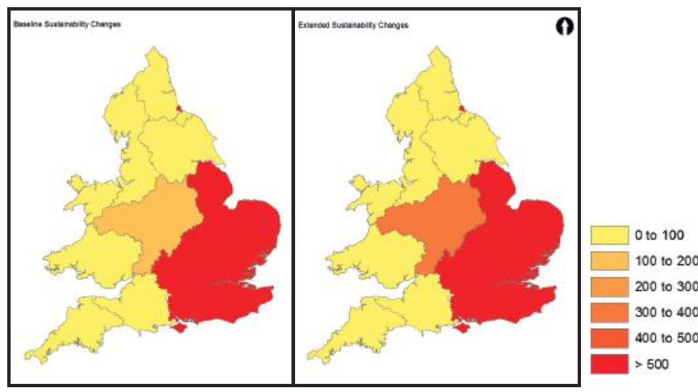


This report considers two levels of abstraction reductions:

- 'base': reductions confirmed as part of the current National Environment Programme plus 25% of potential reductions being considered and yet to be confirmed.
- 'extended': includes all of the potential reductions being considered and yet to be confirmed.

See Fig 6-9 in the main report (the figure here shows a simplified version).

Change in supply-demand balance (Ml/d)



These maps illustrate the scale of reductions in abstraction licences (without any other changes). Potential losses in deployable output by 2025:

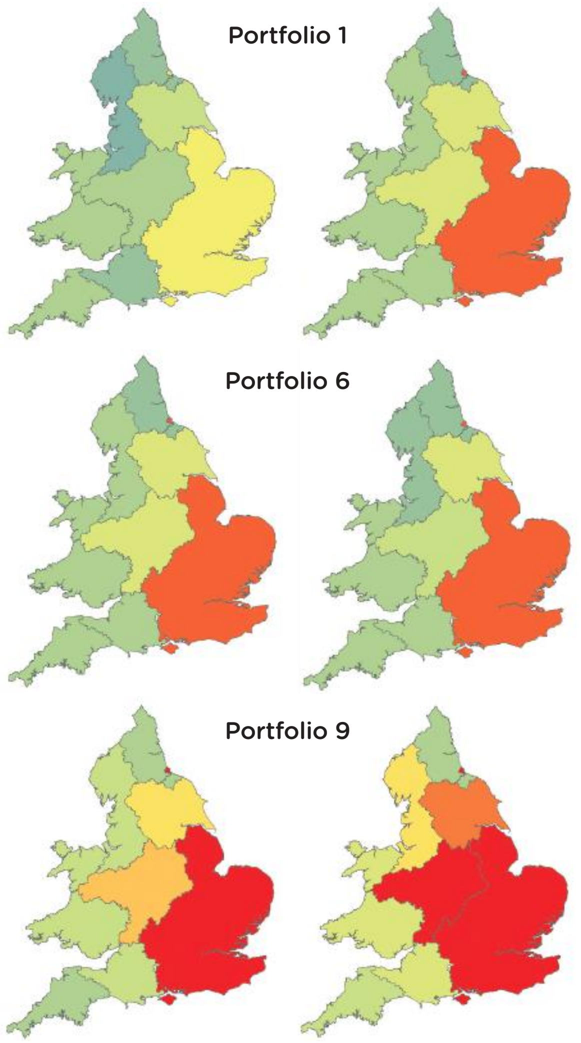
- base (left) and
- extended (right)

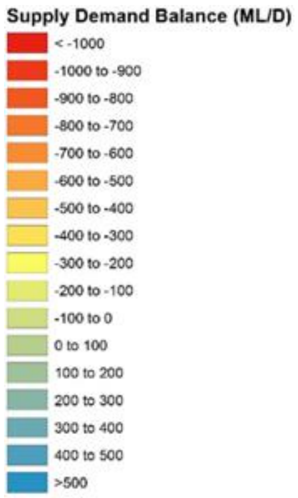
See Fig 6-11 in the main report.

6: Future uncertainty	Future needs are uncertain, so the range of potential future supply/demand balances is large.
(see Section 6.5 for the evidence base)	The future is very uncertain: at the same time there is a decision to be made about how resilient to make the supply system. The risks associated with drought events and climate change could be realised at any time. Reductions in abstraction to protect the environment are material and may be required in the near term. Growth is more gradual. This should be borne in mind when actions to enable the development of a resilient water resource system are being considered. Although many of the risks from climate change will not have yet been realised, the studies and enabling activities that are required to allow potential changes in demand management and infrastructure need to be started given the evolving potential risk that could occur by 2040.

A range of possible scenarios of climate change, population growth and abstraction reductions was explored: 36 potential future scenarios (three drought severity, two climate change, three population growth, two abstraction reductions) and four levels of reduction in demand.

The maps below illustrate the potential scale of deficits in 2040 and 2065 in three potential scenarios prior to implementation of strategies to reduce demand and increase supply.





Scenario	Portfolio 1	Portfolio 6	Portfolio 9
Drought	Historic	Historic	Severe Drought
Climate Change	Baseline	Baseline	Extended
Abstraction	Baseline	Baseline	Extended
Growth	Medium	Upper	Upper
Demand management	BAU Base	BAU Base	BAU Upper

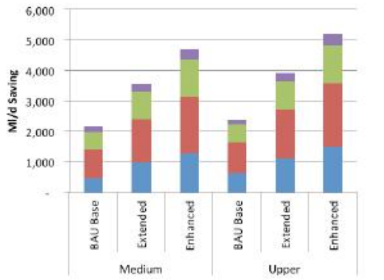
See Figs 6-27 and 6-31 in the main report.

7: Twin track of demand management, new resources and regional transfers	This analysis confirms that a 'twin track' approach, of demand management and new resources (including transfers), is the most suitable strategy for providing drought resilience in the future.
(see Section 8.1 and 8.2 for the evidence base)	There are two means of mitigating a potential deficit between the supply and demand of water in a given supply area: reduce demand through a combination of leakage and water efficiency (household and non-household) measures; and/or increase water available for use in the supply area through investment in new supplies and/or importing water from an area of surplus into the area of deficit. Historically, there has been a general trend in reducing demand in spite of increases in population, as a result of considerable reductions in non-household (industrial) use, and a general reduction in per capita consumption (PCC) through more efficient appliances and increased metering of properties as well as reductions in leakage. New water supplies and more connected systems have also helped address the supply/demand problem. To keep the price of water as low as possible, the water resource management process has always sought to take advantage of lowest cost solutions before implementing more expensive options. The conclusions about appropriate strategies for providing drought resilience were based on a combination of portfolio development, costing of the overall scenarios, resilience testing and evaluation of the practical constraints that might exist in relation to the various options that are available. For each demand scenario, the deficit remaining after demand measures had been implemented was met through local resource development and intra- and inter-regional transfers. Given the high degree of spatial variability in deficits, large-scale transfers of water between companies and regions may potentially offer some of the best value options remaining to address the supply/demand problem, though they face significant technical, environmental and commercial challenges, which require further investigation for the benefits of transfers to be realised.

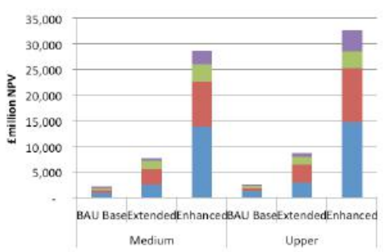
8: Demand management *(see Sections 8.1 and 8.2 for the evidence base)*	**There is a case for considering more extensive measures to reduce water use, both to give a greater level of resilience and to reduce the risk of regretted investment.The levels of demand management that have been analysed in this report are potentially ambitious and rely on significant behavioural change as well as significant future innovation to reduce costs below their current levels to make the options economically feasible.**
	This report has provided an examination of the benefits and costs of demand management based on fairly 'optimistic' assumptions about the level of cost reduction that could be achieved through technological innovation, and policy support for measures such as innovation in tariff structures and levels of demand achieved through new property builds. Achieving cost-effectiveness in the 'extended' demand management strategy would, therefore, require significant policy and regulatory support.

Four demand management strategies were developed and costed.

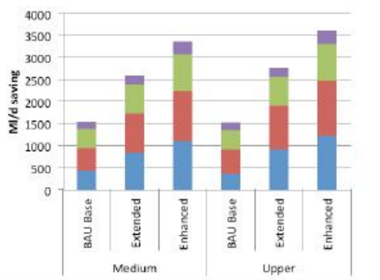
DM Strategy Savings 2065 Ml/d



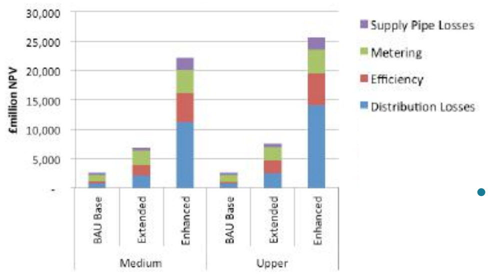
DM Strategy NPV Cost £m 2065



DM Strategy Savings 2040 Ml/d



DM Strategy NPV Cost £m 2040



These figures show the savings (Ml/d) and costs (£m) relative to the BAU Upper strategy. See Figs 8-3 to 8-6 in the main report.

- Business as usual: Upper (poor customer response to initiatives in existing Water Resource Plans)
- Business as usual: Base (expected customer response to stretched targets in current activity types)
- Extended (e.g. combination of smart metering, tariffs, retrofitting to 65% of existing properties to save 40 litres per property; or new builds achieve 105 litres daily consumption per head). Leakage reduced through extended pressure control and active leakage control.
- Enhanced (e.g. all new homes achieve 105 litres per head plus extensive retrofitting, large-scale mains replacement for leakage).

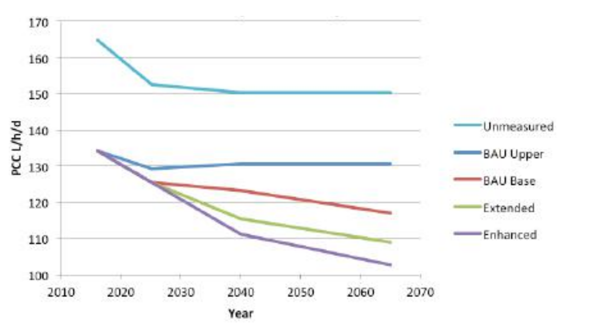
Base and extended scenarios have a similar level of cost-effectiveness. Enhanced demand management is significantly less cost-effective.

Strategies are ambitious: average per capita consumption reduces below 120 litres per head per day even under business as usual.

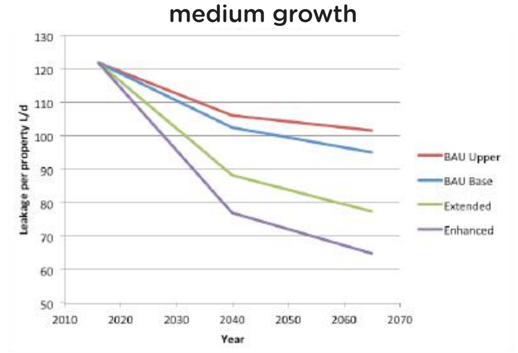
See Fig 8-1 in the main report.

Leakage strategies are ambitious: leakage declines to below 100 litres/property/day even under BAU base.

Forecast per-capita consumption under different demand management strategies

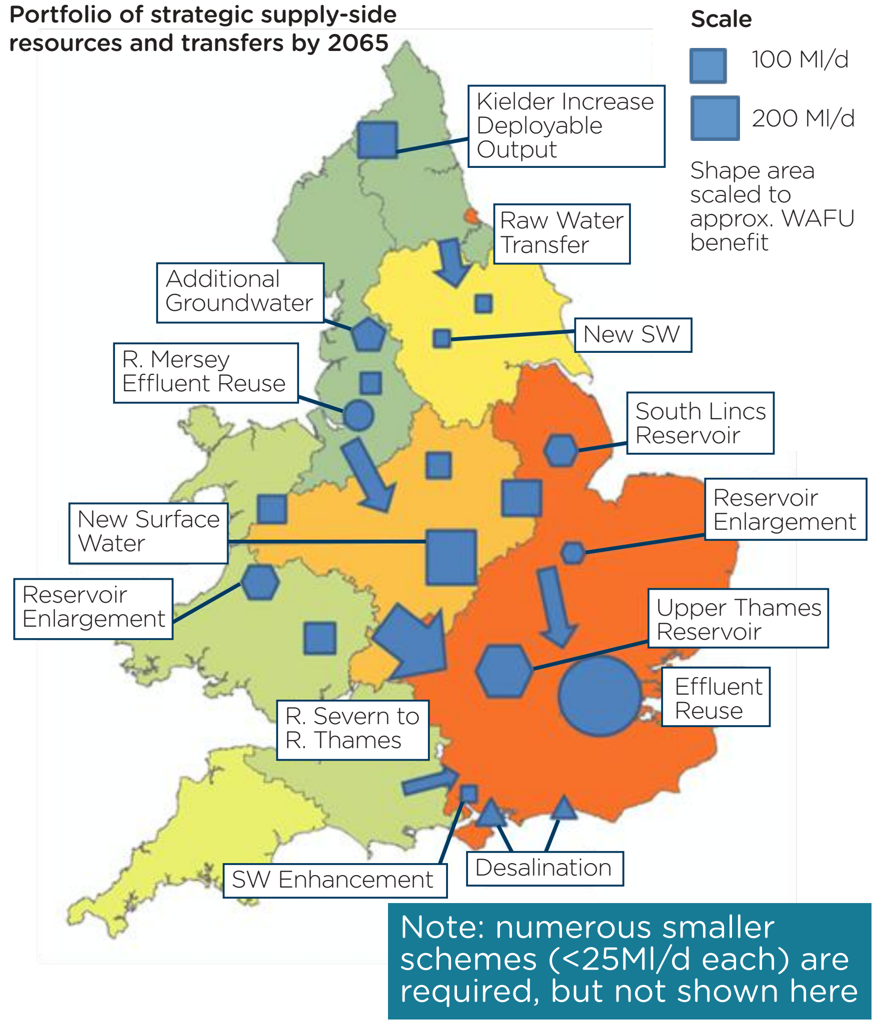


Change in mean total leakage per property 2016 to 2065 medium growth



9: Strategic supply options and inter-regional transfers *(see Sections 8.1 and 8.2 for the evidence base)*	**Large-scale transfers of water between companies and regions, supported by storage and new local resources may offer some of the best value options.**
	The supply/demand analysis conducted for this report demonstrated considerable surplus volumes of water in parts of England and Wales under many scenarios, at least to 2040. For the first time it is possible to identify the scale and distribution of this surplus at a national level under nationally consistent scenarios of future uncertainty in population growth, climate change, changes to abstraction licences and taking account of the likely spatially coherent impacts of drought on deployable output. Supply and demand options differ in cost noticeably between regions. We have assessed where implementing low cost supply/demand options nationally may open up areas of surplus, which could then be utilised to transfer water to areas where the marginal cost of water is significantly higher. Transferring water is expensive due to the mass and distances involved. There are also a number of issues relating to water quality differences between regions and environmental risks for both source and donor region. Given the high degree of spatial variability in deficits, large-scale transfers of water between companies and regions may potentially offer some of the best value options remaining to address the supply/demand problem, though they face significant technical, environmental and commercial challenges, which require further investigation, see 10 below, for the benefits to be realised.

Portfolio of strategic supply-side resources and transfers by 2065

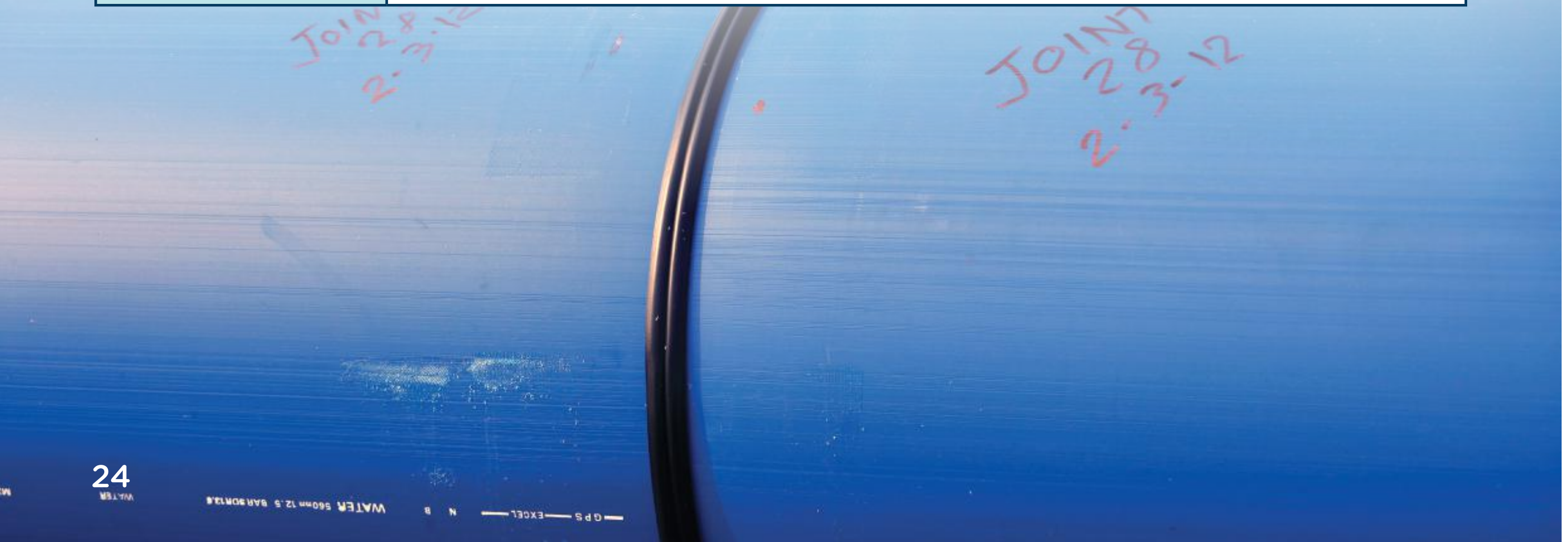


Under the more challenging 2065 future scenarios, a number of strategic supply schemes will be required:

- Large amounts of flexibility can be provided by smaller 'local' supply developments
- Transfers, both inter- and intra-regional are likely to be required, together with appropriate storage, and provide a cost-effective solution
- Major strategic transfer routes to be considered are:
  - River Trent to support storage in Anglian region (plus onward transfer to Affinity)
  - River Severn used to transfer resources to Severn Trent and potentially across to Thames
  - River Tees to supply Yorkshire
- New surface water storage will be needed
- There is no requirement for a wider water grid.

See Fig 8-14 in the main report.

10: Promoting and enabling transfers	Important constraints could limit the feasibility of transfers; the practicability of inter-regional transfers needs further assessment for the benefits of transfers to be realised.
(see Sections 8.1 and 8.2 for the evidence base)	The costs and benefits of strategic transfers have only been examined in this report on a technical basis that accounts for the volumes of raw water involved. Other constraints were applied on a qualitative basis to the conclusions using resilience model testing and consultation with water company practitioners. These 'other constraints' include risks to drinking water quality and the environment, which will need to be carefully analysed if transfer schemes are promoted. The arrangements for storage and abstraction of water in these major river systems is highly complex and issues to be evaluated include: the spread of invasive species; environmental impacts on receiving water courses; and the management of potable water quality risks, such as those associated with the treatment of metaldehyde pesticides. Large-scale transfers could (particularly in the long term) act to change the nature of the resource systems involved, and mean a greater sharing of risks than currently exists between water companies. If existing storage within the supplying river systems cannot be reliably used, then the analysis strongly indicates that alternative new storage would be required within the receiving resource systems. The safety and quality of drinking water, including the acceptability of the aesthetics (e.g. taste, odour, hardness) of water supplied to customers is of paramount importance. Changing the source of water supplied may change the aesthetics and result in customers raising concerns. Mixing water from different sources can result in water quality problems because of the nature of different sources of water. It is imperative that customers retain confidence in the quality of their water supplies. Costs of mitigation options to maintain wholesomeness and confidence need to be considered in the option assessment for transfers of water between regions Achieving the levels of cost-efficiency and benefits from transfers that have been assumed within this report could, therefore, take a considerable length of time and collaboration between multiple stakeholders, and such collaboration should, therefore, be included as a key 'enabling action' to allow cost-effective delivery and development of feasible solutions in the future. As noted in 13 below, it is advisable that some form of adaptive 'road map' should be considered that confirms when decisions to proceed (or not) with the major transfers need to be made, and provides support to infrastructure planning once that decision is in place.



11: Social and economic consequences of severe droughts	Customers place a high value on avoiding severe water use restrictions, in the range £40-£160 to avoid one day of severe interruption to household supplies.
(see Section 8.5.3 for evidence base)	As well as the high social and economic impact felt by household customers when severe restrictions such as standpipes are in place, there are additional economic losses from restrictions on business and public sector water users. For England and Wales as a whole, estimates suggest a 37%[6] loss of non-household Gross Value Added (GVA) at times when the most severe level of restrictions are applied to all non-households; across the whole of both nations that is a loss of approximately £1.3 billion[7] per day.

The consequences of drought have been monetised based on:
- Household willingness to pay to avoid each day of restrictions

(£/HH/yr per avoided expected day of interruption/ year)	S2-S3-TUBs	S4-EDOs
Low	£0.25	£40
Central	£1.00	£80
High	£2.50	£160

- Non-household impact on Gross Value Added due to public water supply restrictions and associated restrictions for private abstractors.

Other monetary or wider consequences of severe drought situations include:
- Environmental impacts of duration of Hands off Flow conditions, and of supply-side Permits/Orders
- Secondary effects e.g. education and hospitals; knock-on effects through the economy
- Direct water company costs.

Illustration of analysis of impact on Gross Value Added

			PWS GVA Loss			Non-PWS GVA Loss		
Industry			S2	S3	S4	S2	S3	S4
Agriculture, forestry and fishing	Rain-fed agriculture	Cereals	N/A	N/A	N/A	0%	15%	30%
		Potatoes rain-fed	N/A	N/A	N/A	0%	15%	30%
		Other rain-fed crops	N/A	N/A	N/A	0%	15%	30%
	Irrigated crops	Potatoes irrigated	N/A	N/A	N/A	53%	59%	59%
		Strawberries	0%	100%	100%	0%	100%	100%
		Other irrigated crops	N/A	N/A	N/A	24%	37%	37%
	Livestock	Livestock	0%	0%	25%	0%	10%	25%
Wholesale and retail trade	Retail sale of flowers, plants, seeds, fertilizers, etc.		0%	30%	30%	15%	30%	30%
	Other wholesale and retail		0%	0%	25%	0%	0%	25%
Arts, entertainment and recreation	Sports activities		50%	50%	50%	50%	50%	50%
	Other arts and entertainment		0%	0%	25%	0%	0%	25%
Manufacturing	Food products, beverages and tobacco		1%	10%	75%	1%	10%	75%
	Textiles, wearing apparel and leather products		1%	10%	75%	1%	10%	75%
	Wood and paper products and printing		0%	0%	50%	0%	0%	50%

Further analysis is provided in table 7.4 of the main report

6 Within a wide plausible range of 20% to 60%.
7 Applying the 37% central figure to the 2013 GVA level (approximately £3.5 billion per day for England and Wales) suggests that severe restrictions across the whole of both nations would cause GVA loss of £1.3 billion.

12: Minimum standard of drought resilience *(see Section 8.5 for evidence base)*	**There is a good case for increasing the level of resilience to drought. The costs of increasing resilience are relatively modest (less than £4 per household customer per annum to achieve resilience to 'severe' events) and the economic benefits far outweigh those costs.**
	In all cases the costs of moving to, or maintaining, resilience to 'severe' events are less than £4/household customer/annum (and only increases to £5/household customer/annum under drier climates, as the relative cost increases). The 'central estimate' of the benefit-cost ratio is greater than 10:1 in all cases and remains greater than 5:1, even if lower bound estimates of the benefits are assumed. There is a strong economic argument for considering a strategy that provides resilience to 'extreme' drought (central estimate benefit-cost ratio of greater than 5:1); this would typically cost less than £8/household customer/annum (£10 under drier climates), compared with the 'baseline' worst historic drought resilience. Note that these costs only include the expenditure involved in demand management and new resource schemes (which includes some allowance for treatment and transfer costs) – where transfers are involved, no allowance has been made for any additional treatment or transaction costs that may be required. Treatment costs could be significant and will rely on the outcome of investigations outlined above. The effect of transaction costs should be modest within a correctly functioning market, and should not significantly affect the findings of the cost-benefit analysis.

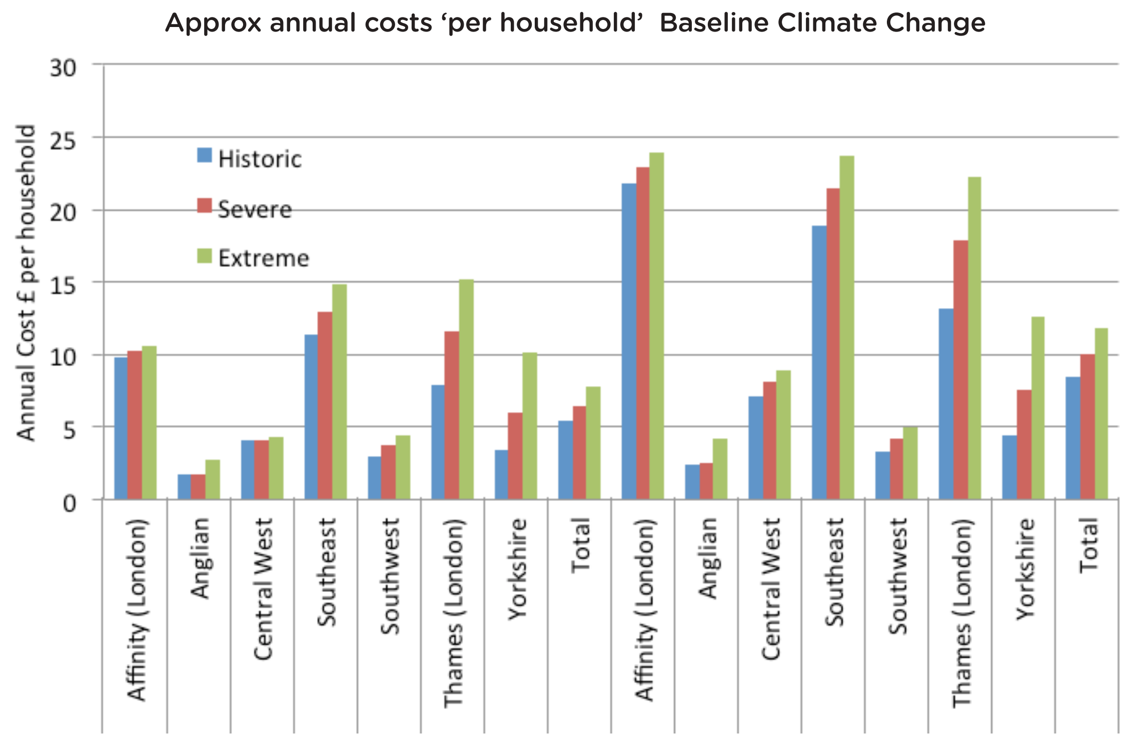
Consequence models have been developed for all deficit sub-regions, based on an analysis of severity 3 and 4 drought restrictions and:

- Relationship between duration and frequency of restrictions
- Willingness to pay and GVA impacts
- Relative probability of future scenarios
- Net present value of incremental costs of providing increasing levels of resilience.

Drought Deficit sub-region	Level of resilience planned for	Net present cost required to achieve change in resilience (£m)	NPV of conseqence benefits: without non-PWS allowances (£m)			With non-PWS impacts		Benefit-Cost Ratio; Lower bound	Benefit-Cost Ratio; Central estimate including non-PWS benefits
			Lower	Central	Upper	Central estimate including non-PWS benefit	Lowest bound, no PWS and Level 4 restrictions only		
Anglian	Severe	£103	£897	£1,262	£1,992	£1,470	£802	9	14
	Extreme	£287	£817	£1,150	£1,816	£1,340	£731	3	5
Bristol	Severe	£47	£305	£490	£862	£540	£276	6	11
	Extreme	£39	£132	£212	£373	£234	£119	3	6
SEEL	Severe	£237	£2,479	£3,177	£4,751	£3,709	£1,706	10	16
	Extreme	£256	£1,423	£1,824	£2,727	£2,129	£979	6	8
Thames - London	Severe	£453	£6,364	£7,258	£9,583	£7,894	£3,974	14	17
	Extreme	£425	£3,125	£3,563	£4,705	£3,875	£1,951	7	9

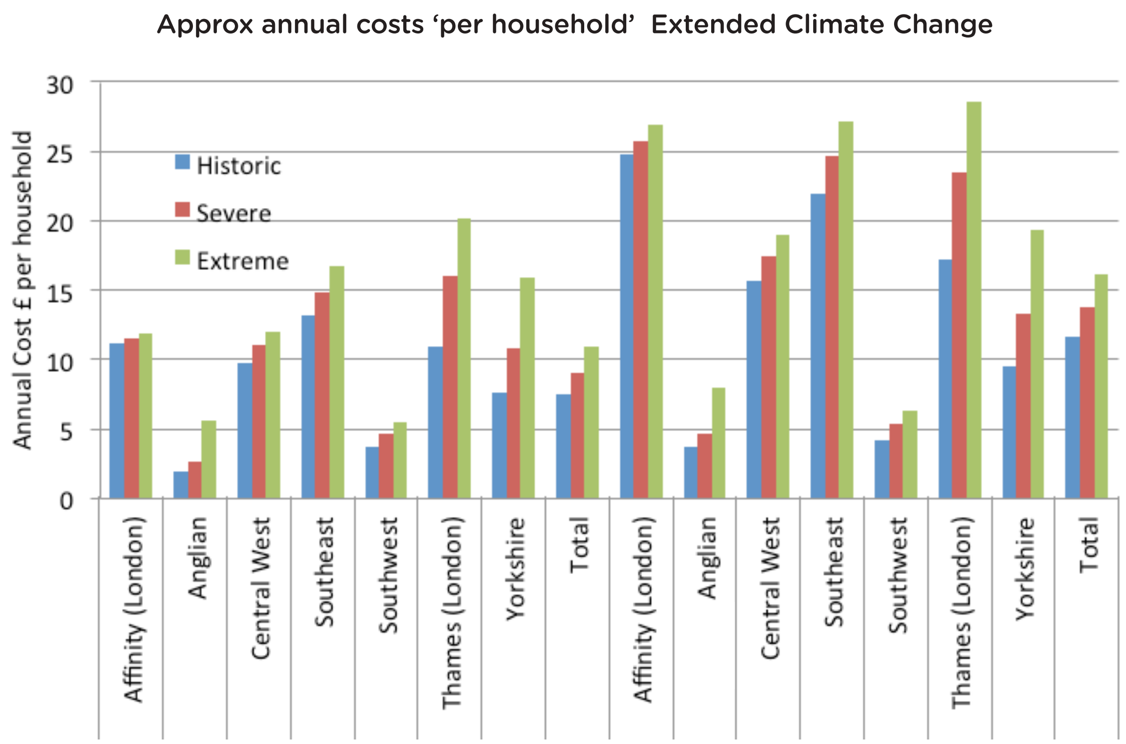
Summary of expected household costs associated with improving levels of drought resilience – from the current situation to being resilient against 'historic' or 'severe' or 'extreme' droughts – under a median climate change scenario.

See Fig 8-31 in main report.



Summary of expected household costs associated with improving levels of drought resilience – under a dry climate change scenario.

See Fig 8-32 in main report.

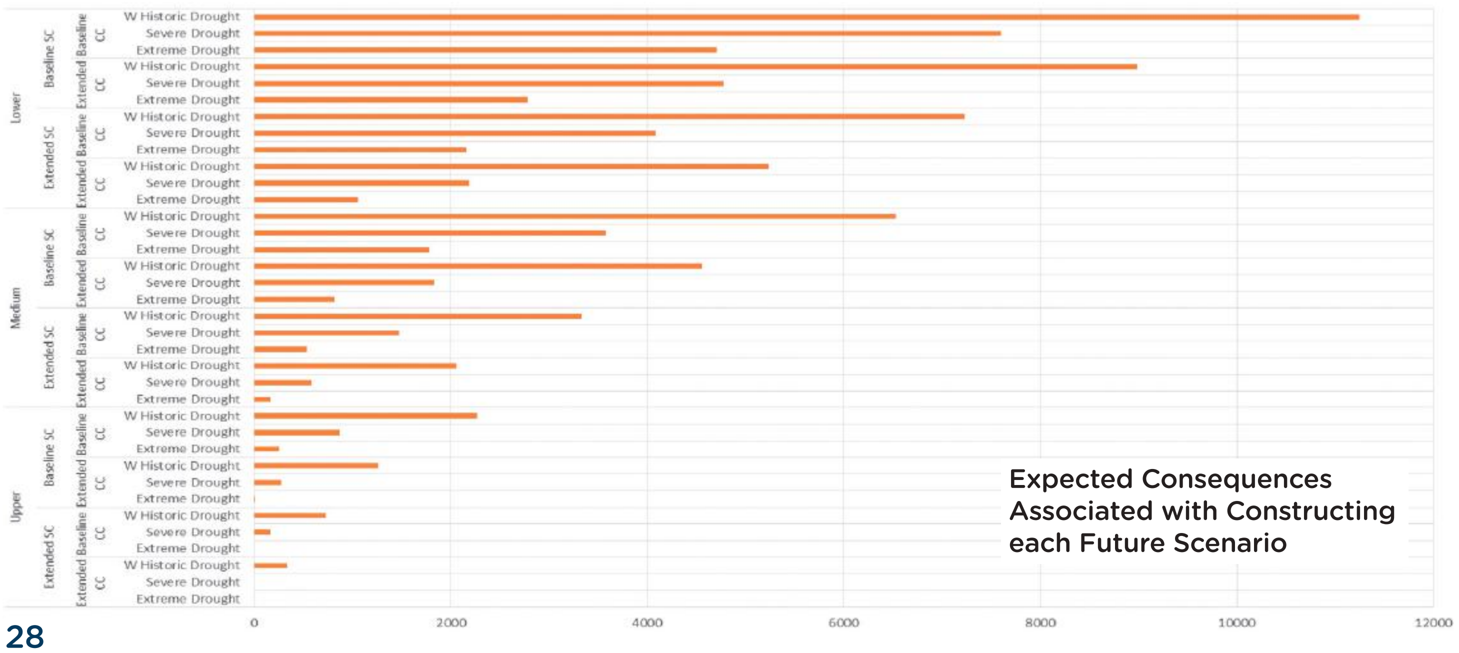


N.B. These costs relate to the amount of expenditure required to address demand in the sub-region where the demand is situated – costs have been generated across England and Wales in accordance with the Portfolio analysis.

13: Adaptive management *(See Section 8.5 for the evidence base)*	**The complex, inter-regional and trans-boundary nature of water resources, combined with the uncertainty over the impact of the different future changes suggest that it would be helpful to develop an adaptive 'road map' to support the timely availability of key strategic schemes and define key roles for large-scale planning.**
	Some risks are immediate and need a prompt response: the risk of drought is present now and the government aims to achieve sustainable levels of abstraction by the 2020s. We may already be facing the effects of a drier climate. The impact of population growth is uncertain and will play out over a longer time, so an adaptive approach that ensures desirable options are retained may be most suitable. Further work is needed to develop triggers and milestones that can be used in a national level adaptive plan, supporting WRMPs. Where risks are within the control of policymakers or can be monitored, it is important to ensure that adaptive actions are given adequate time, and that this is reflected within the WRMP process. Failure to do this could result in either increased risk or costs that are much larger than those proposed within this report. The most cost-effective approaches to increasing resilience require action in the current round of Water Resource Management Plans to avoid having to rely on more expensive options later on. Demand and supply measures both have long delivery times. Significant increases in water efficiency take a long time as they require sustained behavioural and policy changes and require significant investment. Delivering large inter-regional transfers and new storage capacity are complex projects and require lengthy analysis and agreement before beginning work on associated infrastructure, which in itself takes time.

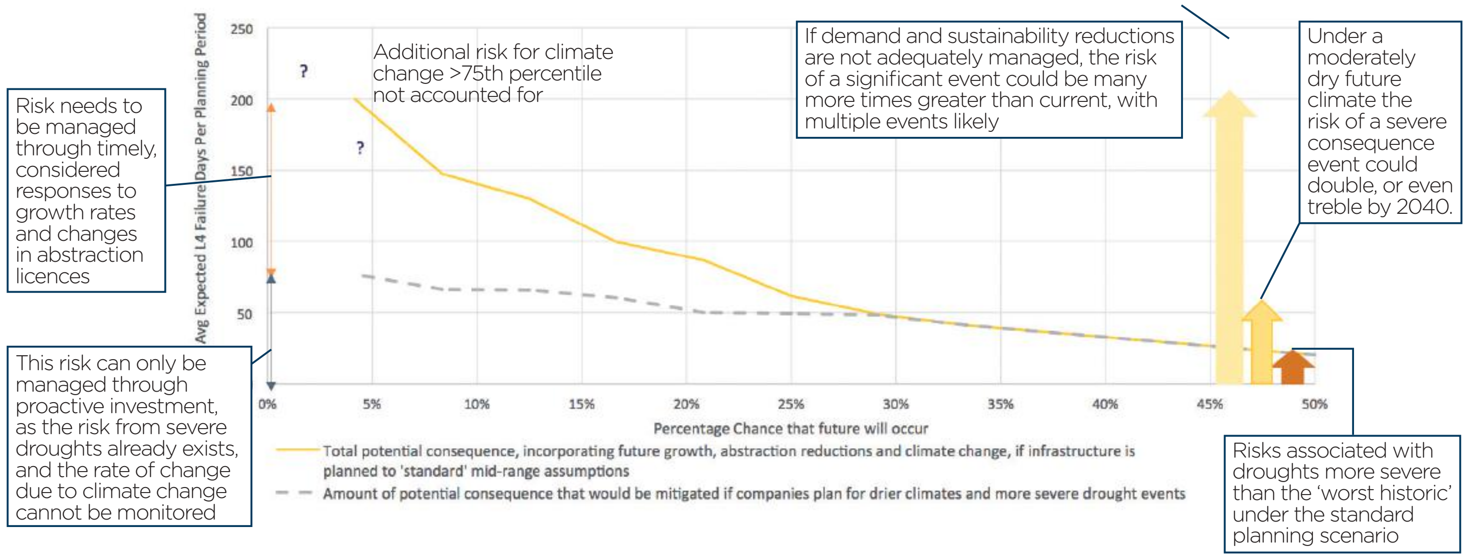
Consequence models, which quantified the relationship between potential future supply/demand deficits, and the risk of emergency drought orders and non-essential use bans, were used to separate out future risks and to evaluate the cost-benefit of different levels of proactive investment. This new approach extended the cost-effectiveness analysis that is typically used in water resource planning, to a cost-benefit based approach. The charts below illustrate the analysis for Thames-London and similar charts are provided for other regions in the main report.

See Figs 8-35 to 8-40 in the main report.



Expected Consequences Associated with Constructing each Future Scenario

Analysis of Conseqence Risks at 2040 – Thames London (compared with 'Standard' planning assumptions)

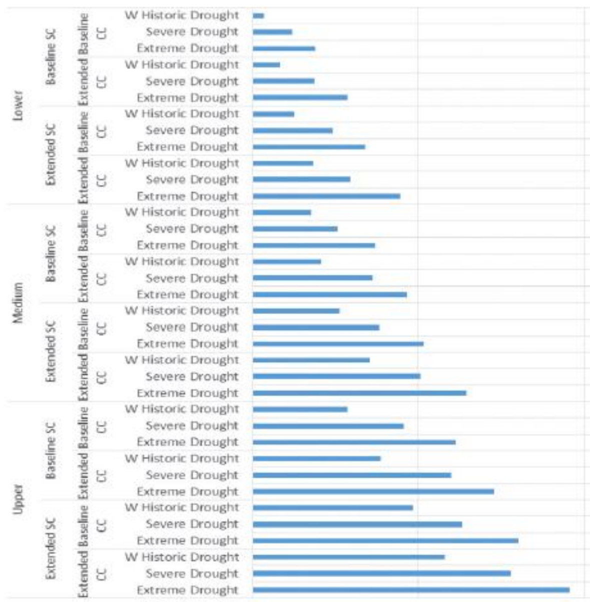


Comparison of costs and benefits Thames-London: This chart compares the NPV costs versus the NPV of expected consequences of developing portfolios to meet each of the 36 future scenarios contained under the BAU Demand Management strategy.

Where the consequences (orange bars) are greater than or equal to the costs (blue bars), then the analysis indicates that it is cost beneficial (based on the assessed probabilities and risks) to proactively plan for that future.

See Figs 8-42 to 8-45 in the main report.

Expected Costs Associated with Constructing each Future Scenario



14: Minimum level of drought resilience *(See Section 8.4 for the evidence base)*	**There is a strong case for the UK and Welsh governments to consider adopting consistent national minimum levels of resilience, recognising that there are significant issues to address, including inter-regional and inter-generational fairness.** Society faces choices about its risk appetite for severe restrictions on water use, such as standpipes: it is not possible to protect against all eventualities. There is a clear need for a step change in companies' engagement with their customers, to allow them to explore the inter-generational and national aspects of water resource decisions made at a company scale. There is a policy question as to whether resilience standards should be based solely on customer engagement and willingness to pay. Historically, customers have found it difficult to evaluate high impact/low likelihood events and issues that cross generations. It is, therefore, possible that customers may not be willing to pay for increased levels of resilience. Companies have a responsibility to secure resilient supplies, and both Ofwat and the Secretary of State have a duty to further the resilience objective in England and Wales. This report has clearly shown there is a significant national benefit to be gained from transferring water between regions in surplus and those in deficit. However, if those regions operate to different levels of service, such transfers may not be possible. To date there has been no consideration of the economic consequences of drought within WRMPs. Some regions (e.g. London) clearly have a higher level of economic 'value' per non-household customer affected, and there are varying levels of reliance on the public water supply by non-household customers. It may, therefore, be important to consider how considerations relating to economic consequence might affect the choice of the level of drought resilience to plan for (and specific options/benefits) when policy decisions are being made. Furthermore, the availability of water to other abstractors, notably agricultural and industrial abstractors, depends upon the resilience of public water supply, which takes precedence in times of water stress. This is another reason why companies' level of resilience is a matter of public interest and public policy. Therefore, the UK and Welsh governments could consider setting clear expectations on minimum levels of service for companies in preparing their Water Resource Management Plans.

For more information contact:
Kate Trumper, Strategy & Policy Analyst,
Anglian Water

Email: kTrumper@anglianwater.co.uk

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Produced by RED
01904 479 500 (S_903)