Water supply and resilience and infrastructure

Environment Agency advice to Defra

October 2015

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Executive summary

This advice report sets out information to support Defra in delivering the Water White Paper[1] commitments related to assessing future needs for water resilience and associated strategic water infrastructure.

In this document, we treat resilience as the capacity to maintain essential services under a range of circumstances from normal to extreme.

Our advice is based on a review of the available evidence across sectors which rely on water and encompasses the economic, social and environmental impacts which would result from compromised supplies.

The review has focused on supply pressures associated with severe and extreme droughts, although it does note some non-drought hazards. The options to enhance resilience levels to drought could have wider benefits in terms of other threats to security of supply.

Our review of the evidence has concluded seven key findings:

1. Large parts of society, industry and commerce are currently exposed to the risk of emergency water restrictions (stand pipes, rota cuts etc.) at a likelihood in the order of 1% every year. The risk is often uncertain and is probably understated in some water company plans. The future risk of emergency water restrictions is likely to increase due to a combination of growth pressures and changes to droughts associated with climate change, unless water companies and other businesses invest to maintain current resilience.

2. The consequence of emergency water restrictions has the potential for severe economic, societal, reputational and environmental impacts – particularly in large conurbations. One study estimated the monthly cost for London alone at £7 – 10 billion[2]. Although the evidence is not well developed it is possible that the societal impacts of such restrictions could include break-down of social cohesion and serious impacts on public health. One estimate of the economic cost of an extreme, three year drought in England in the 2050s could be up to £80bn if it leads to serious demand restrictions in London and the South East, although this does not take into account adaptation and investment already planned by water companies[3].

3. Initial work shows that the benefit of enhancing water resilience is likely to exceed the cost. Further work is required across sectors to understand better the cost-benefit ratio under a range of future scenarios, against a scale of resilience outcomes.

4. The planning processes to ensure suitable levels of resilience for public water supply are in place at a water company level, for example the water resources management planning process. They have delivered improvements in companies' plans for managing supply and demand but have had less impact on increasing resilience as they focus on maintaining the supply-demand balance at the same

[1] Water for life - https://www.gov.uk/government/publications/water-for-life
[2] Thames Water, 2012, Water Resources Management Plan, Appendix J, p1 http://www.thameswater.co.uk/about-us/5392.htm
[3] AECOM, Strategic Infrastructure and Resilience – http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&ProjectID=18964&FromSearch=Y&Publisher=1&SearchText=wt1535&SortString=ProjectCode&SortOrder=Asc&Paging=10#Description

level of risk. A number of barriers appear to have limited any significant progress on resilience and strategic infrastructure since privatisation. These include lack of:

- supporting evidence around risks
- incentives for improving resilience in the longer-term
- knowledge of the costs and benefits of mitigation actions.

There are also real or perceived regulatory barriers and limitations in customer support, affordability and planning across multiple companies. There are similar perceived concerns about barriers to collaborative planning with other sectors, although it is not clear whether this is due to barriers or lack of incentives.

5. While many individual businesses plan their future needs, there is no strategic sectoral planning for the risks associated with water for energy security, agriculture, industry, commerce and private water supplies reliant on direct abstractions.

6. Severe droughts would cause significant deterioration in the environment, partly due to continued or unplanned emergency abstraction. Properly planned water supply resilience solutions are likely to reduce the frequency and impact of drought measures on the environment in both severe and less severe droughts. Therefore increasing resilience is likely to benefit the environment.

7. There are a number of gaps in the evidence which could be addressed to assist resilience planning. These include a more detailed understanding of the multi-sector costs and benefits of increasing resilience.

Based on our assessment it is our advice to Defra that a next phase of this work should be undertaken to provide a clear evidence base to support the planning processes for water. The work would present the case for enhanced levels of water supply resilience both for public water supply and other major sectors through an assessment of options for alternative levels of resilience. It would set out the potential role for strategic infrastructure for multiple sectors.

Contents

1. Purpose and scope

This advice report sets out information to support Defra in delivering its Water White Paper[4] commitments related to assessing future needs for strategic water infrastructure and resilience. The supporting annexes set out further detailed evidence.

The report covers the current and future resilience of the public water supply, power generation and agricultural sectors to the water resources hazards primarily of drought, but also noting some of the other hazards. The report does not contain advice about specific water supply options.

The responsibility for assessing and planning for water supply resilience, and for delivering any strategic infrastructure to improve resilience, continues to rest with individual businesses. The primary responsibility for public water supply planning remains with the water companies.

2. Current and future levels of resilience

2.1. Public water supply

Water companies plan for future water demand through statutory water resources management plans, while the actions the companies will take in a drought are set out in their drought plans. Companies plan 25 years ahead, as a minimum, and include an allowance for water supply outage due to short-term hazards, such as pollution, as well as a planning margin known as target headroom to manage long-term uncertainties, such as changes to growth forecasts.

Companies manage their response to droughts through their planned level of service. The level of service is the planned frequency of customer demand restrictions that will be imposed during a drought. The level of service and therefore the impact on bills is agreed between the company and its customers. Hence, a company's level of service is an agreed measure of the drought resilience that its customers expect. Levels of service vary between companies with some companies stating the yearly risk of standpipes/rota cuts as being 1% or lower and some stating 'never' or 'unacceptable'. However it is important to note that these calculations of frequency are based on historical records, and therefore companies might not be able to avoid severe restrictions if there is a drought worse than previously experienced.

Water companies have a statutory obligation under the Security and Emergency Measures Direction to ensure that water supply services are maintained at all times amounting to a minimum of 10 litres/head/day of potable water. Customers generally use around 150 litres/head/day[5] and therefore a reduction of this magnitude for any long period of time is likely to be considered unacceptable.

Impacts of failure

It is not feasible to plan to avoid standpipes or rota cuts altogether: there could always be a drought event worse than the one planned for. AECOM estimated the economic and social

[4] Defra, *Water for Life*, December 2011.
[5] http://www.waterwise.org.uk/pages/faqs.html

costs of an extreme 3 year drought in the 2050s would be up to £80 billion, although this work has some important caveats and this figure should be understood as a high level guide to the order of magnitude of costs involved[6]. The impact of such a drought is likely to have far-reaching consequences and could cause major disruption to businesses, public health and social cohesion. AECOM noted that a large proportion of the costs would occur in the River Thames catchment due to demand from London, and that the risk of standpipes or rota cuts is greatest in the South East.

Severn Trent Water estimated that the cost of the flooding of the Mythe treatment works, which caused loss of supply to 350,000 people, was between £25-35 million[7]. This incident demonstrated the limits on bowser provision and bottled water and the risks to social cohesion in what was still a relatively limited loss of supply event.

Most water companies state that standpipes are impractical for large urban areas and that rota cuts are the only alternative to unmanaged loss of supply as pressure fails under reducing supplies. There are many practical and serious public health concerns with regards rota cuts and stand pipes that are clearly recognised by water companies, DWI and Public Health England.

2.2. Power generation

Approximately 20% of England's electricity is produced by freshwater cooled power stations[8]. A reliable water supply is vital for the safe operation of these plants. Freshwater cooling relies on a relatively small volume of water: only 310Ml/d was used for cooling in 2013, compared to 16,070 Ml/d for public water supply. Other power generation capacity is located on the coast and estuaries and mainly uses seawater for cooling with smaller freshwater needs supplied by a mix of public supply and direct abstraction.

Forecasts for the freshwater needs of the power industry in the future are variable. They show that demand could increase or decrease depending on the future electricity generation mix, the uptake of carbon capture and storage (CCS), the future location of new plants and the cooling technology used[9]. The Case for Change report considered a range of energy futures and showed that in the short-term we might expect a small increase by 2030, but in the longer term most scenarios showed a fall by 2050s, with the total range of forecasts falling between +13 to -370 Ml/d.

Approximately one third of the electricity generated using freshwater cooling is in areas classified as over-abstracted / licensed in the local Catchment Abstraction Management System (CAMS)[10]. The Case for Change highlighted that under some scenarios this would increase to approximately half of the freshwater cooled electricity. This means that the future resilience of those supplies is at risk and may need new investment in water security.

Overall, the power industry takes a much larger share of all actual licensed abstraction (approximately 45%): the vast majority is for hydropower (98%), but this only produces approximately 0.5% of England's electricity.

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[6] AECOM, Strategic Infrastructure and Resilience – http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&ProjectID=18964&FromSearch=Y&Publisher=1&SearchText=wt1535&SortString=ProjectCode&SortOrder=Asc&Paging=10#Description.
Further notes on the caveats around the figures used in this report can be found in the annexes

[7] Severn Trent Water (no date) Gloucester 2007 The impact of the July Floods on the Water Infrastructure and Customer Service. Final Report. Available from http://www.stwater.co.uk p38

[8] See Annex

[9] Environment Agency - Forecasting future water demand by the electricity generation sector, 2014, p22

[10] Hands off flow constraints on licences are conditions that require abstraction to reduce and/or cease as river flows reduce leading to access to water being less reliable depending on the flow levels at which they operate.

New or redeveloped inland power generation capacity may require new measures to provide sufficiently secure cooling water (e.g. reservoir storage or transfers) especially in locations where water resources are already scarce and the environment under pressure from abstraction. There is not currently any national system of water planning for the power industry.

New or redeveloped coastal power generation capacity may face different resilience hazards such as sea level rise and coastal erosion.

Impacts of failure

Future energy security and long term planning for power generation capacity has been the subject of much debate and consideration in recent years and work on this is continuing. Society and the economy are highly dependent on secure power supplies and public water supply requires reliable power to operate.

Potential sources of heightened risk in future for power generation in relation to water availability are:

- Decreasing margins between supply and demand and mothballing of generating capacity reduce flexibility of the grid to respond to local water shortages;
- Lower river flows as a result of climate change or more severe droughts reduce water availability for cooling – often with no back-up;
- Increased river water temperatures as a result of climate change reduce the effectiveness of cooling. For example the heat waves may limit production of nuclear power stations[11]
- Additional water needed for carbon capture technologies.

AECOM reported that reduced water availability has a constant relationship with generation from a plant, so that a 50% reduction in water availability would lead to a 50% reduction in power generation. The grid can be operated flexibly, meaning that it is possible that other stations could take up some of the slack, or electricity could be imported from Europe. It is therefore difficult to forecast the impact of water availability on national power production without further evidence. However AECOM notes that any fall in domestic energy production has far-reaching impacts for the rest of the economy: the domestic electricity, transmission and distribution sector has an output multiplier of 2.3, meaning that if the sector's output were to fall by 1%, UK output would fall by 1.3%[12].

Work by Vivid Economics, following the 2012 drought, indicated that if the drought had continued and rainfall had remained at 80% of long term average into 2013 then the cost of turnover in the energy industry would have been approximately £1.2 billion[13]. However it is important to note that this impact would likely be offset by increases in other power stations not affected by drought.

2.3. Agriculture

Abstraction for agriculture is approximately 1-2% of total actual licensed abstraction[14]. However, water is a very important resource for the agricultural sector and in some places, in the summer, agricultural abstraction can be a significant portion of the water taken from

[11] Kidd, Steve – Nuclear Engineering International 22 June 2009
[12] AECOM - Strategic Water Infrastructure and resilience, Annex C, p18 March 2015. http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&ProjectID=18964&FromSearch=Y&Publisher=1&SearchText=wt1535&SortString=ProjectCode&SortOrder=Asc&Paging=10#Description

[13] Vivid Economics, The Impacts of Drought in England, 2013, p37
[14] Environment Agency Abstat data, 2013.

the environment and little is returned after use. The future demand for water from agriculture will be affected by policy, global markets and climate change.

The three most important irrigated crop categories (potatoes, field vegetables, and soft fruit) account for 85% of the total volume of irrigation water abstracted annually. About half of these abstractors are located in catchments classified as 'no water is available'[15]. This indicates that water demand may exceed available supply, particularly if climate change, other sectors' growth or environmental needs reduce water availability further.

The Case for Change highlighted the lack of demand forecasting for sectors other than the water industry. Since then we have undertaken further work to assess the future demand forecasts of the food and drink sector. These forecasts have shown considerable uncertainty in demand forecasts but do not indicate large increases (see Annex 4). The Food Security Report recommends that further modelling is completed to assess the future water demands for agriculture[16].

Impacts of failure

The Vivid Economics analysis of the 2010-12 drought indicated that the cost to the agricultural industry was in the region of £79 million; the vast majority of this being the loss of irrigated potatoes[17]. If the drought had continued, the loss to the agricultural sector could have been around £0.2 billion before considering any offsetting output increases (e.g. in other areas or from other products).

2.4. Other industry

Water use in sectors not covered in the sections above, accounts for around 5.5% of actual abstraction according to the abstraction returns data received for 2013. This equates to approximately 2000Ml/d[18] and major water-reliant industries include food and drink, mining and quarrying, chemicals and paper industries and manufacturing. In general water abstraction under this category is likely to be more directly linked to the country's economic performance although analysis to support this has not been undertaken by the Environment Agency.

[15] http://www.foodsecurity.ac.uk/assets/pdfs/water-synthesis-report.pdf
[16] http://www.foodsecurity.ac.uk/assets/pdfs/water-synthesis-report.pdf p1
[17] Thames Water, 2012, Water Resources Management Plan, Appendix J, p1 http://www.thameswater.co.uk/about-us/5392.htm
[18] See Annex.

Due to the returned abstraction data we have a good understanding of the current and recent use of the water in this category. However there is little or no strategic water planning for the sector as a whole. Therefore it is difficult to assess how far different sectors understand the future economic value of this water and the value of additional resilience planning for these industries. Some sectors have taken a lead in this area such as the food and drink industry who developed the voluntary Federation House Commitment aimed at reducing water use in food manufacturing[19].

3. Gaps in our understanding of resilience

There are gaps in our knowledge and understanding in forecasting future water availability, demand and risks. This section describes some of the areas which we recommend are considered further in order to facilitate effective decision-making on increasing resilience.

3.1. Cross sector

Assessing new strategic options

AECOM's high-level assessment of the resilience characteristics of various option types showed that:

- desalination and direct water re-use provide the greatest resilience to water supplies under severe and extreme drought;
- a mix of option types can enhance resilience against a wide range of pressures/uncertainties; and
- leakage reduction, metering and water efficiency are long-term sustainable measures to reduce water demand and therefore improve environmental resilience.

We also believe that transfers between companies are an important way of increasing resilience. It is also important to make sure that catchment management options are considered appropriately as these may have benefits for both the environment and abstractors and wider society, for example reducing flood risk.

A review of options for enhanced resilience could investigate the location, size and flexibility of potential future options to increase resilience.

National policy statement for water

The Planning Act 2008 allows the Secretary of State to produce National Policy Statements (NPS) related to Nationally Significant Infrastructure Projects (NSIP). For water supply, the only NSIPs are reservoirs with a capacity of over 10,000 Ml and transfers with a capacity of

[19] The Federation House Commitment (FHC) was developed to help companies in the food and drink sector to reduce water use across their manufacturing sites and ran from 2008 to 2014. This was a voluntary agreement which is managed in partnership between WRAP, Food and Drink Federation (FDF) and Dairy UK. All companies that sign up to the FHC agreed to make a contribution to the food and drink industry water reduction target of 20% by the year 2020, against a 2007 baseline. The FHC has delivered an overall 16.1% reduction in water use and now is directly managed by the food and drink Industry given its success.

100,000 Ml/a[20]. A recent scheme which would meet the NSIP criteria is the raising of Abberton Reservoir by Essex and Suffolk Water[21]. The need for a NSIP can be justified across water sectors.

An NPS should be based on good evidence. In our view, further work on the impact and cost of infrastructure failure and the benefits of increasing resilience is needed to support any decisions on whether an NPS is appropriate and what it should contain. The government could consider widening the definition of a NSIP for water supply to cover other water resources infrastructure and scales.

Cross-sector planning and co-operation

There are very few examples where cross-sector planning and investment has occurred. It is not clear whether this is due to barriers or lack of incentive. However we do note that the varying funding mechanisms might well be a barrier.

There are also relatively few examples of within sector co-ordination. The Water Resources in the South East group is one example of co-operation within the water industry, which has resulted in coordinated planning between six water companies and has led to more integrated plans and six new cost-effective transfers.

The Water Resources East Anglia project is in its start-up phase but has the clear ambition to explore multi sector involvement within the future planning for Anglian Water.

There are also some examples of farmers co-operating. For example the Lincoln Water Transfer group has a licence which allows its 19 members to share water between them from 25km of drainage ditches[22].

Recent research by Cambridge University highlighted that the current financing and regulatory channels for investing in water infrastructure were limited to public water supply and not designed for multi-sector investment. Using a case study of the Wissey Catchment they examined four alternative financing models. The report stated that the multi-sector collaborative approach could 'provide greater resilience across sectors.'[23] Therefore there is potential both within sectors and across sectors for more co-ordinated and concerted planning and we advise that further thought should be given to mechanisms that might allow this.

3.2. Public water supply

The value of resilience

Government has advised water companies that the preferred solutions in their water resources management plans should be best value for their customers and the environment. To date, the government has relied upon the water resources management plan process and the discussion between the companies and their customers to set appropriate levels of service. However, from our working with companies and other regulators/stakeholders we are concerned that the value of resilience and security of supply is not currently being adequately assessed and that the resulting plans may not deliver suitable levels of resilience. The barriers to enhanced resilience within planning are complex but appear to include lack of guidance, regulatory support/incentives, asymmetries between local and wider values of resilience, and the evidence base. Going forward, there should be an explicit focus on the costs and benefits of resilience within future plans. The value of resilience also requires a more comprehensive approach to planning which

[20] Planning Act 2008, section 27 and 28
[21] As a result of Abberton scheme, which included raising Abberton reservoir, the deployable output of the Essex zone increased by 67 Ml/d. Ref: Essex and Suffolk final WRMP p49.
[22] UKIA, Working together to protect water rights, 2011
[23] University of Cambridge, Sink or Swim: A multi-sector collaboration on water asset investment, p9

encompasses a multi company and multi sector approach to avoid sub optimal investment decisions being made.

Severe droughts and water availability

Water companies assess the amount of water they have available, known as deployable output, on the 'worst [drought] event on record'. Hence, historical drought events determine the deployable output assessments of (most) water companies.

A review of the plans of the six companies of the WRSE Group found that the severity of hydrological events that underpin deployable output estimates varies from approximately 1 in 20 year to 1 in 200 year return period[24]. We estimate that the deployable outputs for water companies in the South East may be between 7 – 16% below what is in their water resources management plans for a drought with an annual frequency of occurrence of 0.5%. There may need to be clearer guidance to companies to ensure that they understand the amount of water available in a drought and adequately plan for the consequences.

Some companies have used, or are considering using, stochastic drought sequences to test their available supplies against a greater range of droughts than the historic record[25]. This will allow them to assess how their sources behave under more extreme conditions.

We believe there would be some benefit for companies to be able to test their plans against a consistent set of droughts. This would provide confidence that companies are considering a range of appropriate scenarios and allow inter-company transfers to be consistently assessed.

The UKWIR Extreme Droughts sensitivity matrix might provide a methodology and means of presentation which could allow companies to test and present the sensitivity of their water supply systems to more severe droughts than those on record[26].

Levels of service

Each water company sets its planned level of frequency of restrictions with its customers, which means that companies plan to different levels of drought resilience.

While the planned frequency of demand restrictions should be down to how much customers are willing to pay to avoid them, the government may like to consider whether it has a role in planning for extreme events, since the use of standpipes or rota cuts could lead to wide-ranging social, economic and environmental consequences.

Some companies state that their planned rota cuts and standpipes frequency is 'never'. In reality this often means 'never' as long as the company does not experience a drought event any worse than those on record, i.e. rota cuts / standpipes could be needed for more severe droughts than previously experienced. Therefore, the planned level of service may not be as resilient as stated.

The Water Act 2014 enables the Secretary of State to set the level that a water company needs to plan for, to cope with droughts. The government may want to understand the costs and benefits of planning to cope with different drought levels before using this power.

Non-drought hazards

It is notable that water supply failures over the past decade have been primarily non-drought related. For example, the flooding of the Severn Trent Water's Mythe treatment works near Tewkesbury in 2007 left 350,000 people without potable water for between 7-10 days[27]. Other potential risks include extremes in temperature, pollution,

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[24] Environment Agency, Drought Scenario Pilot, 2014 (unpublished) [ref annex instead?]
[25] Southern Water included stochastic drought sequences its WRMP14.
[26] Annex
[27] Ofwat, Resilient Supplies, Nov 2010, p6

telemetry/communications and asset failure. Some of these individual risks have been addressed: for example, the Pitt Review recommended that critical infrastructure was protected up to 1 in 200 flood event[28].

We do not have a comprehensive assessment of how resilient water company water resource zones are to non-drought hazards, such as flooding and pollution incidents. Water companies do assess outage as part of their planning and include an outage allowance in their planning.

Given the diverse nature of risks, many of which are unknown, there is some value in considering the consequences of failure of individual components of infrastructure, without considering the cause[29]. This could help identify critical infrastructure and allow targeted investment to improve resilience.

3.3. Power generation

The government has stated that carbon capture and storage (CCS) 'has a critical role to play in reducing emissions in the UK'[30] Plants fitted with CCS technology consume from 44% to 84% more water per unit of power than traditional fossil fuel fired power stations, due to an increase in cooling and process uses[31].

The government's policy on energy mix, and the freshwater cooling demands for different energy sources, will dictate how much water is required in the future. The need for water for both CCS and consumptive water use for the energy industry should be considered in the context of water availability. Cross sector planning and forecasting will be important to understand interdependencies and maintain the resilience of the energy industry and other sectors.

3.4. Agricultural resilience

Often demand for water reflects the economic value of the goods produced. We believe that abstraction licence reform should encourage a market for water which will better reflect its economic value.

Forecasting future agricultural water use is complex as there is a number of complex and interrelated influences on agricultural demand for water including, world markets, EU policy and climate. It is therefore difficult to predict how the impact of failure will increase in the future although further work would improve confidence in this area.

4. Next steps

We believe that further work is needed to understand the strategic water resources infrastructure and resilience needs for England, and what won't be delivered by existing planning processes.

We recommend a programme of work is completed by July 2016 which would assess and inform the multi-sector resilience options and possible strategic infrastructure requirements for England. The timescales of this work would then allow the finding to be considered within and inform the next round of Water Resource Management Plans 2019. This work would include:

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[28] Pitt Review – Paragraph 15.39
http://webarchive.nationalarchives.gov.uk/20080906001345/http://www.cabinetoffice.gov.uk/~/media/assets/www.cabinetoffice.gov.uk/flooding_review/pitt_review_full%20pdf.ashx
[29] Butler, Presentation - Preparing for the Unimaginable, 2015
[30] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/381859/Top_40_Annex_FINAL.pdf
[31] Adaptation sub-committee – Progress report – Managing climate risks, 2014. P74

- Understanding demand at a multi-sector, regional scale and the risks and synergies of multi-sector planning
- Consider the current and future supply capacity
- Review the costs and benefits of increasing resilience across sectors
- Understand the costs and implications of increasing water company levels of service for severe restrictions i.e. standpipes/rota cuts.
- Consider what strategic options can increase resilience across sectors.

Annex 1 – Background and context

Water White Paper commitments

The Water White Paper is a call to action. It describes: *'a vision for future water management in which the water sector is resilient, in which water companies are more efficient and customer focussed, and in which water is valued as the precious resource that it is'*[32]. It outlines the challenge that climate change and population growth present for future water resources, and the case for action to build resilience and ensure a good quality water environment.

The Environment Agency's *Case for Change – current and future water availability*[33], published alongside the Water White Paper set out new scenarios for water availability in the 2050s to illustrate the scale of the challenge, and the level of uncertainty involved in planning for this changing future.

The Water White Paper stated that:

- *'The Environment Agency will take an overview of interconnection options across all licensed water supplies in order to provide a challenge to a company's assessment in its Water Resources Management Plan of the potential for bulk transfers. It will also consider further whether there are environmental barriers to large scale transfers through existing river and canal systems.'*[34]
- '*The Environment Agency will develop demand scenarios in partnership with different sectors, and use the outputs to develop a common understanding of the future risks to both the abstractors and the environment and provide advice to Government.*'[35]
- '*Government will take a strategic overview of the quality and capacity of water and wastewater infrastructure, and the robustness of the sector's plans for future service delivery.*'
- '*Government, the Environment Agency and the water industry will also consider further whether there are strategic national infrastructure projects necessary to ensure water supplies remain resilient and, if so, whether there are barriers to their delivery that should be removed.*'[36]

These commitments were made within a wider context of Water White Paper aspirations that include:

- behavioural change, customer focus and managing water demands
- abstraction reform
- wider regulatory, governance and market reforms
- fit with wider planning – e.g. river basin management plans and ecosystem services.

[32] https://www.gov.uk/government/publications/water-for-life, p3.
[33] Environment Agency, *The case for change – current and future water availability*, December 2011, Report – GEHO1111BVEP-E-E
[34] https://www.gov.uk/government/publications/water-for-life, p26
[35] *Ibid*, p52
[36] *Ibid*, p46, p54.

2010/12 drought

England and Wales experienced a prolonged period of below average rainfall from 2010 to early 2012, including two dry winters. This highlighted the vulnerability of our water supply system to drought, particularly the prospect of a third dry winter. Following the drought, the Environment Agency produced a report incorporating the recommendations of the National Drought Group with a detailed action plan. The main actions on resilience were:

- *review and progress appropriate levels of resilience through the water resources and drought planning processes (including consideration of temporary use bans, drought orders and drought permits). This work will include a review of domestic and business customers' willingness to pay for improved levels of service*
- *encourage farmers, power station owners and other major water users to review and, where cost effective, increase their resilience against drought*

During the 2010/12 drought, water companies led a collaborative project to scope strategic options for a third dry winter. These included ideas such as moving water by tanker from overseas, temporary desalination and emergency transfers of water using canals or overland pipes. Where appropriate individual companies have continued to assess and develop these options for their drought plans and/or water resources management plans.

Current related projects

The Environment Agency contracted AECOM on behalf of Defra to assess the social and economic impacts of severe and extreme droughts; and to assess the options to increase future water supply resilience across all water-reliant sectors. Where relevant this report and the annexes provide evidence from AECOM's work.

Water resources and drought planning guidelines

The water resources planning guideline is currently being updated and will be consulted on this autumn. The guideline will allow companies greater flexibility to choose methods which are appropriate to them, including those that will help them build resilience into their decision making.

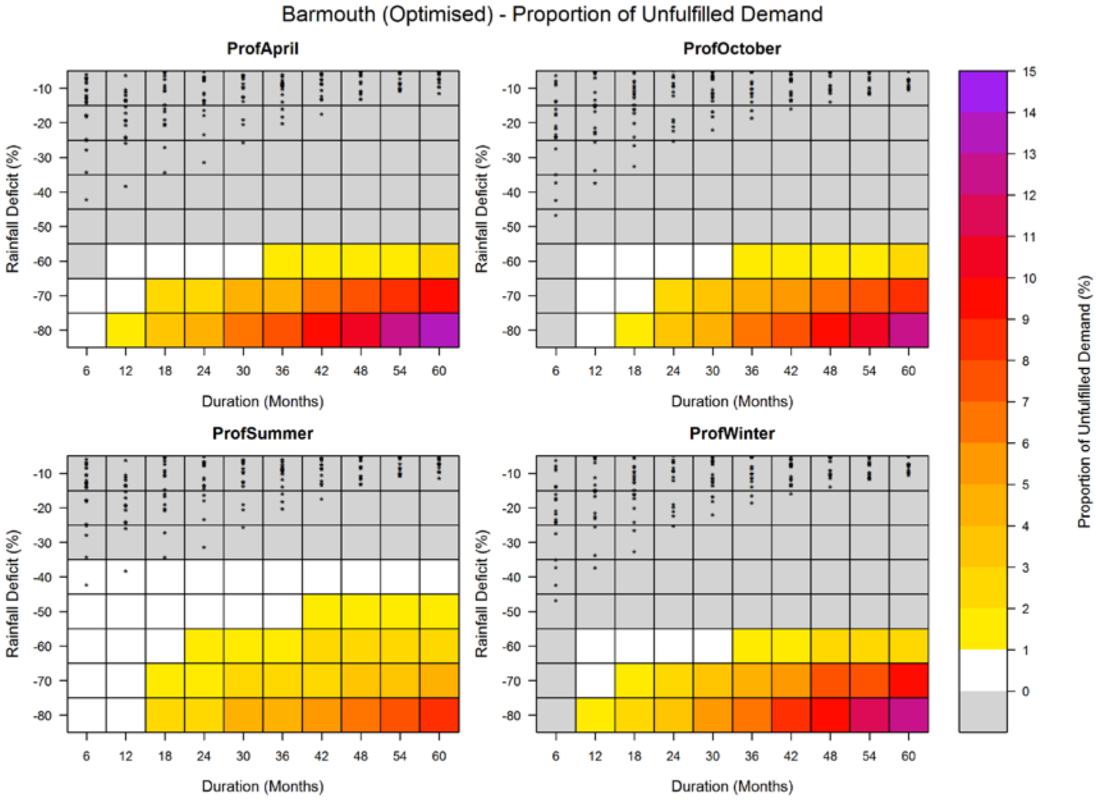
The drought plan guideline encourages companies to consider droughts worse than on record, including long-term droughts and set out how they would manage these situations.

UKWIR Extreme drought project

UKWIR's Extreme drought project[37] characterised the sensitivity of different types of water supply systems to a range of droughts, including those that are more severe than the worst case historical droughts for which the supply systems have previously been tested. The project built simplified water resources models of a selected number of water company resource zones and tested against droughts which varied in length and severity.

A particular strength of the project was the simple and clear way in which the results were presented. The following charts show an example resource zone which illustrates existing droughts as black dots, and the size of deficits occurring under various drought types.

[37] Environment Agency, Defra, UKWIR – Performance of water supply systems during extreme drought



Barmouth (Optimised) - Proportion of Unfulfilled Demand
ProfApril
ProfOctober
ProfSummer
ProfWinter
Rainfall Deficit (%)
-10
-20
-30
-40
-50
-60
-70
-80
Duration (Months)
6
12
18
24
30
36
42
48
54
60
Proportion of Unfulfilled Demand (%)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

Annex 2 – What is resilience?

Resilience definitions

There are a range of hazards outside a company's control that could impact its ability to maintain water supply. These include natural events, such as droughts, heat waves, extended cold periods and floods; and man-made hazards, such as acts of terrorism, and failure of third party services such as energy and communications. Hazards can be inter-related and complex, for example the inter-connected relationships between the environment, water resources, water supply, water quality and wastewater systems.

Resilience has a plethora of definitions. Various organisations, including the Cabinet Office and Ofwat, and academics have previously published definitions of resilience. The following is a list of previously used definitions:

> '*the ability of a system to withstand shocks and continue to function.' (Ofwat 2010)*[38]
> *(customer friendly definition as tested by research) – 'the ability to maintain essential services under extreme circumstances' (Ofwat 2011)*[39]
>
> *'the ability of assets, networks and systems to anticipate, absorb, adapt to and/or rapidly recover from a disruptive event' (Cabinet Office 2011)*[40]
>
> *'the ability of the environment, economy and society across England to withstand and recover from water supply shortages, with a focus on shortages caused by drought events that are more severe than those currently planned for' (AECOM 2015)*[41]
>
> *'the degree to which the system minimises level of service failure magnitude and duration over its design life when subject to exceptional conditions' (Butler 2015)*[42]

We feel that the definition of water supply resilience agreed at the December 2014 CIWEM conference on resilience is useful. It is an amalgamation that brings together the main aspects of the other definitions:

'Resilience is the capacity to maintain essential services under a range of circumstances from normal to extreme. It is achieved through the ability of assets, networks, systems and management to anticipate, absorb and recover from disturbance, whilst ensuring the environment and ecosystems support that and can also recover to their original state. It requires adaptive capacity in respect of current and future risks and uncertainties as well as experience to date.'[43]

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[38] Ofwat, Prevention, protection and preparedness – how should resilient supplies be achieved?, November 2010.
[39] Creative Research for Ofwat, Attitudes to water services in a changing climate: report of research Findings (volume 1), June 2011.
[40] Cabinet Office, Keeping the country running: natural hazards and infrastructure, October 2011, s2.11
[41] cc.
[42] Butler, *Preparing for the unimaginable*, presentation at WRMP24 workshop, March 2015
[43] *Water Act resilience in practice*, December 10th 2014, CIWEM Post Event Report. Environment Agency, December 2014

How to plan for resilience?

The UKWIR good practice guide to resilience planning[44] is an appropriate and effective approach for assessing overall resilience. It sets out three main steps:

- Establish an 'all hazards risk register', recording all the influences on resilience to be considered, the potential disturbances to service that they can cause and the nature of the disturbance including: timing, magnitude, distribution, duration, and any other pertinent characteristic. Hazards in combination should be considered as well.
- Evaluate current and future resilience to each hazard, potential mitigation and improvement measures. Quantify the solutions, including whole-life cost and benefits, and compare their contributions to resilience.
- Chose the preferred solution(s) and seek support, including funding.

The Cabinet Office[45] sets out an initial framework for considering resilience properties of current assets, networks, systems and management. It looks at what resistance, reliability, redundancy and response and recovery they offer. While this framework is useful it is also important to consider such factors as flexibility, adaptability and mitigation should be explored as well.

An alternative approach is that promoted by Professor Butler, who proposes that resilience should be assessed by looking at what can go wrong with a system, rather than the threats to it, since it is difficult to identify all possible risks but easier to understand the impacts of failure[46].

Ofwat notes that '*It would not be feasible to ensure that services are protected from external hazards in all circumstances. This would be an enormously complex, disruptive and expensive task'*[47].

Therefore when considering increasing benefits, the costs and benefits must be carefully considered; there is no blank cheque for maintaining or enhancing resilience. It is also valid to consider reducing resilience and to acknowledge that not all identified hazards will be covered either currently or in the future. Some aspects may be 'safe to fail' or too expensive to mitigate. Industry and government must ensure that the approach, assumptions, decisions and conclusions are transparent to ensure wide understanding and acceptance.

Investing in resilience is likely to need a variety of approaches. Resilience investment should not only be directed at capital schemes: opex investment such as water efficiency measures will also be important. Resilience investment may not all be for permanent schemes: improving and preparing the pool of measures that can be deployed on a temporary basis during severe or emergency conditions may be an equally important alternative.

We advise that the following be considered in resilience planning:

- the level of risk – it is not feasible to ensure that services are protected from all external hazards in all circumstances – there is no such thing as zero risk
- environmental resilience through an integrated catchment planning approach, where possible.

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[44] UK Water Industry Research, Resilience planning: good practice guide, summary report, 2013, 13/RG/06/2.
[45] Cabinet Office, *ibid*
[46] Butler, *Preparing for the unimaginable*, presentation at WRMP24 workshop, March 2015
[47] Ofwat, Resilient supplies: how do we ensure secure water and sewerage services?, November 2010.

- multi-sector resilience including options or permutations of options that provide the most integrated benefits across all sectors.
- climate change
- uncertainties considered through adaptive planning
- cost-benefit analysis

the approach, assumptions, decisions and conclusions around resilience planning should be transparent. This should include what is and what is not planned for.

Annex 3 – Cost of failure

AECOM study

Background

AECOM was commissioned by the Environment Agency and Defra to consider the costs of various drought scenarios. The report produced considered the impact of drought on businesses with their own abstraction licences and the water company restrictions on their domestic and business customers[48].

In calculating these costs of the different drought scenarios AECOM had to make some assumptions. Some points to note are summarised here:

- the project scope did not cover modelling water company supply systems, therefore deficits identified should not be translated to water company deficits, but are instead indications of water availability. The future scenarios did not include infrastructure planned by water companies or any adaptation measures

- deficits associated with the environmental scenarios are a worst case scenario and include rivers where good ecological status may not be possible due to technical feasibility or natural conditions

- it was assumed that an extreme drought in the present day would not need severe demand restrictions, meaning that the report concludes a large difference between the costs of droughts now, and those in the future. As water company supply systems were not replicated, it is not proven that an extreme drought in the present day would not need severe demand restrictions

- AECOM calculated water availability under various drought scenarios. As it did not have access to water company models it had to make assumptions about when drought restrictions would be brought on. It assumed that if the deficit in a region was less than 50Ml/d there would be lesser drought restrictions (i.e. temporary use bans). If the deficit was greater than 50Ml/d then enhanced drought restrictions would be needed (i.e. rota cuts and standpipes). Although this isn't particularly representative of water company supply systems it provides a useful snapshot of one particular scenario.

- Energy sector impacts – The report assumed that a drought that results in a reduction in production at a given power station would be met by increased production at power stations that are not affected by drought. As such, it has been assumed that the economy does not experience indirect effects of drought such as restricted access to electricity. As such, the indirect impacts are not estimated within the report.

- The drought scenarios that AECOM created found that the issues are mainly concentrated in the South East and East Anglia. The work may underestimate some of the costs in the North and West as these water supply systems are often more vulnerable to shorter droughts than those in the South East.

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[48] AECOM, Strategic Infrastructure and Resilience – http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&ProjectID=18964&FromSearch=Y&Publisher=1&SearchText=wt1535&SortString=ProjectCode&SortOrder=Asc&Paging=10#Description

The droughts that AECOM tested were:

- Extreme (approx 0.2% annual chance) and severe (1% annual chance)
- 30 day, one year and three year droughts[49]
- Drought happening today and in 2050

Results

In a one year extreme drought today AECOM calculated the costs as being £477 million, with the large majority of this economic impact being on spray irrigators. For a 3 year drought the annual costs were similar to a 1 year drought.

The following table indicates the annual cost to various sectors of a three year extreme drought in 2050 and the impact on total profits.

Sector	Economic Impact (£m)	Future Gross value added[50] (£m)	% of Future Gross value added
Agriculture - crop production (spray irrigation)	556	749	74.3
Agriculture - crop production (other)	41	1,710	2.4
Agriculture - animal production	68	4,954	1.4
Freshwater aquaculture	2	35	6.5
Manufacture of food products and beverages	750	40,834	1.8
Manufacture of paper and paper products	100	5,988	1.7
Manufacture of chemicals and pharmaceutical products	270	18,923	1.4
Manufacturing (other)	1,276	75,548	1.7
Production of electricity	181	3,403	5.3
Construction	6,986	180,795	3.9
Services	33,439	561,722	6.0

The following table summarises the costs for the various droughts that are examined in the report. The cost is compared against the total of the water companies' AMP5 investment for context.

Note that we do not believe that AECOM's methodology is sufficiently robust to categorically rule out enhanced demand restrictions in a three year baseline drought. We might expect a similar household impact in the baseline to an extreme three year drought. There might also be some impact, albeit not as large, of an extreme one year drought, or 3 year severe drought.

Also as mentioned above, some water company supply systems are more vulnerable to short term droughts. Therefore, in some areas, an extreme one year drought might well lead to some enhanced demand restrictions and the related socio-economic impacts.

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[49] The river flow for the three year drought event is the annual minima of a 1,095 day running mean time series that represents the 1 in 100 or the 1 in 500 year drought condition.
[50] Gross value added (GVA) measures the contribution to the economy of each individual producer, industry or sector in the UK

£m[51]	Baseline				Future (2050)			
	One-year drought		Three-year drought		One-year drought		Three-year drought	
	Severe	Extreme	Severe	Extreme	Severe	Extreme	Severe	Extreme
Estimated economic impact	261	477	880	880	275	275	43,488	43,488
Estimated social (household) impact	0	0 See text above	0 See text above	0 See text above	0	0 See text above	35,958	35,958
Estimated total impact	266	482	887	890	280	281	79,459	79,459
Economic impact as a proportion of capital expenditure in AMP5	1%	2%	4%	4%	1%	1%	361%	361%
Regional breakdown (economic only)								
South East	189	189	449	449	129	129	43,066	43,066
Anglian	72	188	431	431	98	98	200	200
Midlands	0	78	0	0	37	37	222	222
North West	0	21	0	0	11	11	0	0
North East	0	0	0	0	0	0	0	0
South West	0	0	0	0	0	0	0	0

Notes: Orange cells indicate that the lesser drought restrictions would be applied to that region; red cells indicate that enhanced drought restrictions would be applied; green cells indicate that no drought restrictions would be applied. Columns may not sum due to rounding.

NERA Report

Thames Water commissioned NERA to examine the costs to its domestic and business customers of applying drought restrictions. The results suggested that customers would be prepared to pay £65.40 to avoid a day of complete water restriction i.e. rota cut/standpipe, and £0.10 to avoid a day of non-essential use restriction. For business customers the results were reported as ranges: businesses would pay between £25 and £57 to avoid a day of non-essential use restriction and between £436 and £1,010 to avoid a day of complete restriction.[52]

[51] Values are reported in 2011 prices.
[52] Thames Water, 2012, Water Resources Management Plan, Appendix J, p1 http://www.thameswater.co.uk/about-us/5392.htm

Annex 4 – Demand for water

This annex sets out the current demand for water using the latest abstraction data. It then examines the three largest users of water in more detail; setting out the current demand in context and any forecast future changes in demand.

Current demand

The Environment Agency licenses water abstraction from surface and groundwater above 20m3. Abstraction for hydropower and fish farming is non-consumptive, i.e. the water is returned at, or very near, to the point of abstraction. If these two types of abstraction are excluded, then public water supply was approximately 84% of abstraction in 2013.[53].

The following table shows the impact of with and without hydropower and fishfarming for actual abstraction in England only in 2013.

	Public water supply	Fish farming, etc	Other industry	Electricity supply	Spray irrigation	Agriculture (excl. spray)	Private water supply	Other	Total
Total abstraction	14155	2475	1987	4945	265	68	24	91	24010
%	59	10	8	21	1	<1	<1	<1	100
Abstraction **(without hydropower and fish farming)**	14155	0	1987	319	265	68	24	91	16910
%	84	0	12	2	2	<1	<1	1	100

Future forecasts

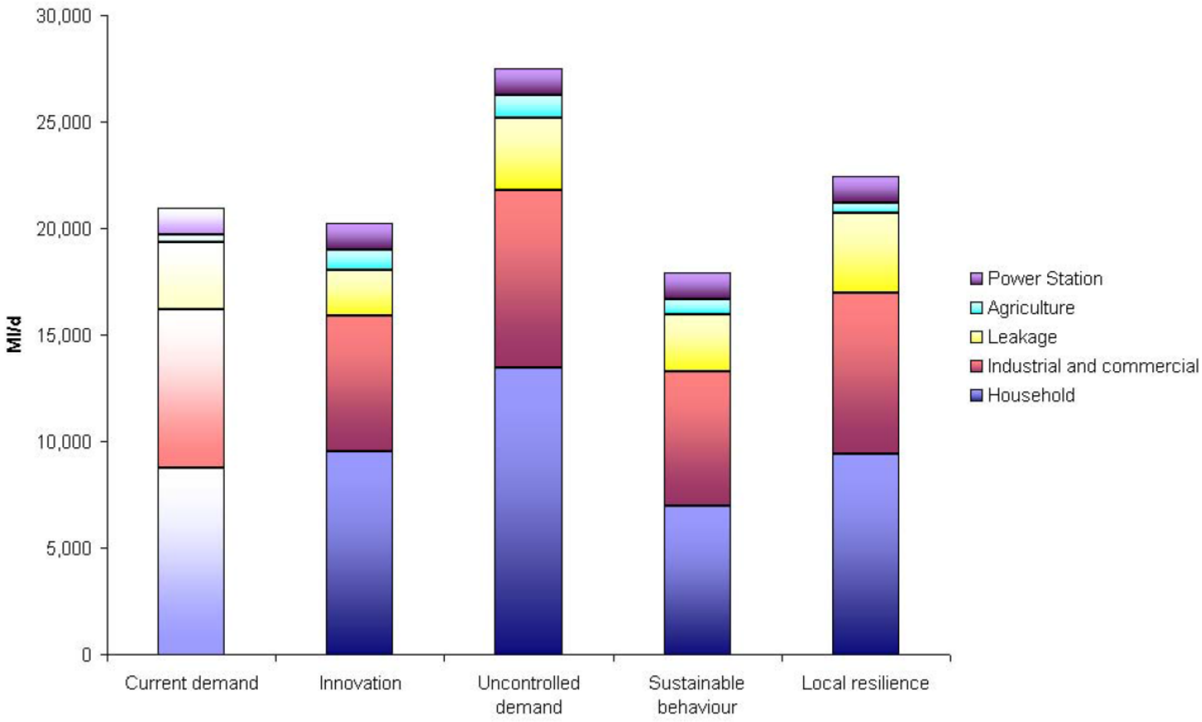
The Case for Change considered how demand might vary under different societal scenarios to identify the envelope of possible future demands. The scenarios are shown in the diagram below[54].

[53] Environment Agency 2013 Abstraction data
[54] Environment Agency, Case for Change 2013 p25

The Case for Change estimated that demand for water in the 2050s could change as follows under the four water demand scenarios.

Scenario	Change in water demand from current by 2050
Innovation	- 4%
Uncontrolled demand	+35%
Sustainable behaviour	-10%
Local resilience	+8%

It showed the breakdown for these scenarios for different users of water in the graph below:



Trends in total water demand 2008-2050 (England and Wales)[55]

Vivid Economics estimated the economic costs of an extended 2012 drought. They assumed that rainfall continued from April onwards at 80% of long term average. The graph below shows the total reduction in profit of various industries. Public water supply, the power industry, irrigated potato farming and landscaping services take the largest impacts[56].

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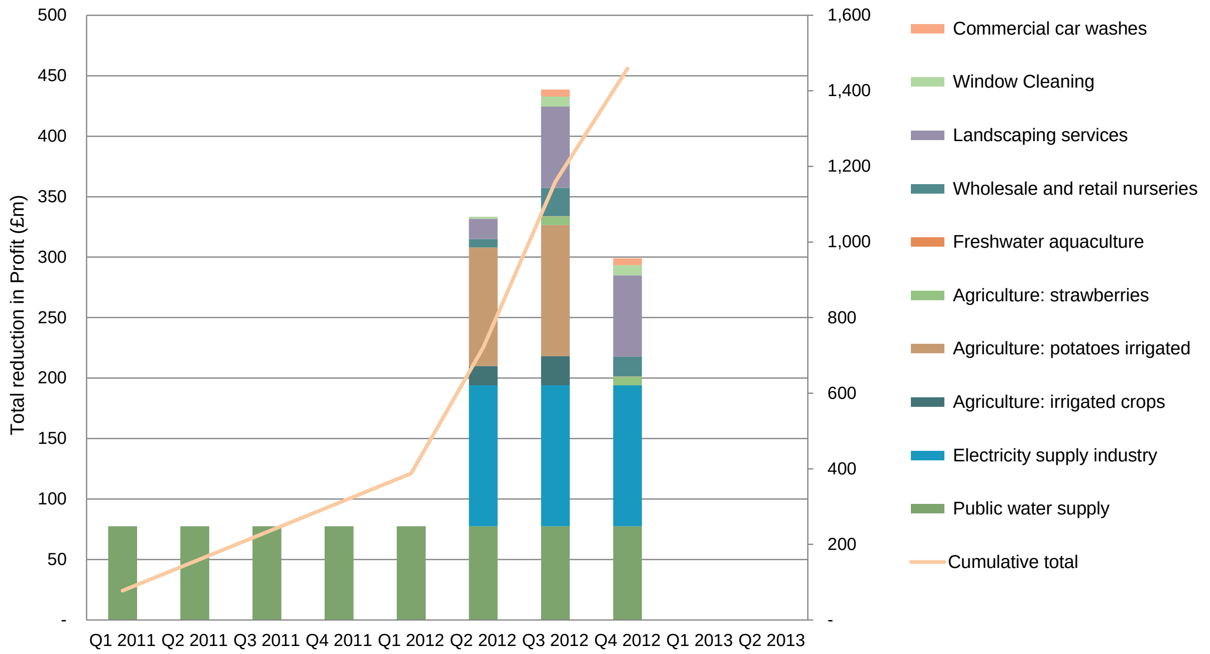
[55] Environment Agency, Case for Change, 2013. P26
[56] Vivid Economics, The economics of drought, 2012, p39

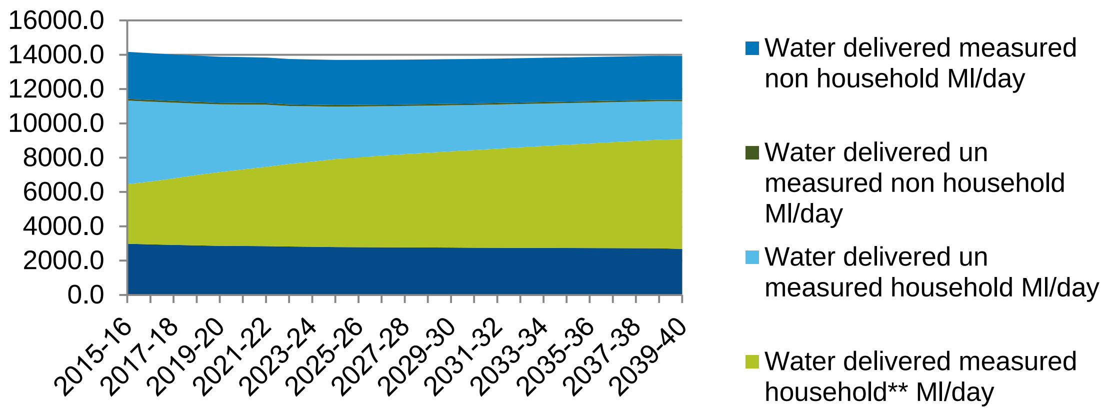


Public water supply

Current demand

The water industry in England currently abstracts just under 14, 000 Ml/d, although is licensed to take much more than this.[57] Recent abstraction figures have shown that there hasn't been a large variation in water abstracted over the last 10 years[58].

Total water industry demand in '000 Ml/d from final WRMP2014 data – England only



Future forecasts

The water industry faces substantial challenges from increasing demand, due to population growth, and reducing supply, due to environmental and climate change reasons.

[57] Environment Agency abstraction figures from 2013 (Abstat)
[58] *Ibid*. Since 2000, the highest public water supply abstraction in England and Wales was 17370 Ml/d in 2003 and lowest at 15799 Ml/d in 2009.

The industry has a well established planning cycle, which enables the water companies to plan how they will respond to these challenges. The industry has proposed a mix of demand management measures and new resources to address these challenges over the next 25 years in water company water resources management plans, which means that the overall demand for water remains approximately level over this period (see figure). Beyond 2030, it may be that water demand grows as population growth exceeds any savings made by planned demand management.

The Case for Change work estimated that the plausible envelope of future public water supply demand in the 2050s is from 28% lower to 49% higher than today's demand.

Power industry

Current demand – non hydropower

Around 60% of all power plants in England are cooled with sea or tidal water, including all nuclear power plants. Approximately 20% of electricity produced requires freshwater cooling[59]. In 2012, approximately 550Ml/d of freshwater was used for cooling power plants, of which around half was returned to the environment[60].

Almost all electricity generation that relies on freshwater abstraction is situated in catchments that currently have sufficient water available. Only two power stations that rely on freshwater for cooling are located in areas where there is not enough water available for abstraction and the environment during an average summer.

The remaining power stations that are reliant on freshwater are located in catchments that have sufficient water available year round. This is because freshwater abstraction for electricity generation generally takes place in the lower reaches of large rivers like the Trent and the Humber that are at a lower risk of being affected by low flows[61].

The following table shows the consumptiveness of various types of power generation.

Water abstraction and consumption rates for major power generation sources[62]

	Cooling		Technology	Abstraction (litre /MWh)	Consumption (litre /MWh)
	Tower	Generic	5,005	3,055	%
Nuclear	Once-Through	Generic	201,619	1,223	61
	Pond	Generic	32,050	2,773	0.6
	Tower	Combined Cycle	1,150	900	9

[59] Environment Agency – Internal briefing, Current and future electricity generation in freshwater catchments, 2014
[60] Adaptation sub-committee – Progress report – Managing climate risks, 2014. p74
[61] *ibid*
[62] Macknick, J., Newmark, R., Heath, G., & Hallet, K. C. (2011). *A review of operational water consumption and withdrawal factors for electricity generating technologies*. Available at: http://www.nrel.gov/docs/fy11osti/50900.pdf

Natural Gas	Once-Through	Steam	5,469	3,755	78
		Combined Cycle for CCS[63]	2,255	1,718	69
		Combined Cycle	51,735	455	76
	Pond	Steam	159,113	1,091	0.9
		Combined Cycle	159,113	1,091	0.7
	Dry	Combined Cycle	27,049	9	0.7
	Inlet	Steam	9	1,546	0.03
	Tower	Generic	1,932	3,123	-
Coal	Once-through	Subcritical	4,569	2,141	162
		Supercritical	2,414	2,241	47
		IGCC[64]	2,769	1,691	93
		Subcritical with CCS	1,773	4,282	61
		Supercritical with CCS	5,805	3,846	-
		IGCC with CCS	5,105	2,455	66
		Generic	2,664	1,137	48
	Pond	Subcritical	165,250	514	43
		Supercritical	123,144	468	0.3
		Generic	102,696	2,478	0.4
	Tower	Subcritical	55,576	3,541	2
		Supercritical	81,439	191	6
		Steam	68,400	2,514	0.2
Biopower	Once-through	Steam	3,991	1,068	4
	Pond	Steam	159,113	1,364	27
	Dry	Biogas	-	159	0.9

Current demand – hydropower

Approximately 0.45% of power in England is generated by hydropower. The largest hydropower schemes in England are[65]:

[63] CCS - Carbon capture/storage
[64] IGCC - Integrated Gasification Combined Cycle
[65] https://en.wikipedia.org/wiki/Hydroelectricity_in_the_United_Kingdom Accessed August 2015

Name	Operator	Capacity (kW)
Beeston Weir	Novera Energy	1,676
Franklaw Hydro at Franklaw Water Treatment	United Utilities PLC	1,000
Kielder Power Station	Northumbrian Water Ltd	5,500
Mary Tavy Power Station	South West Water Ltd	2,600

Some hydropower schemes are unable to operate at low flows and therefore are affected by drought and water availability. However, given the relatively small contribution of hydropower to the grid, this report has not examined its resilience.

Future forecasts

Any increase in water scarcity or temperature in the future may reduce the capacity and effectiveness of freshwater cooling water systems, although power companies categorise this as a low-medium risk[66].

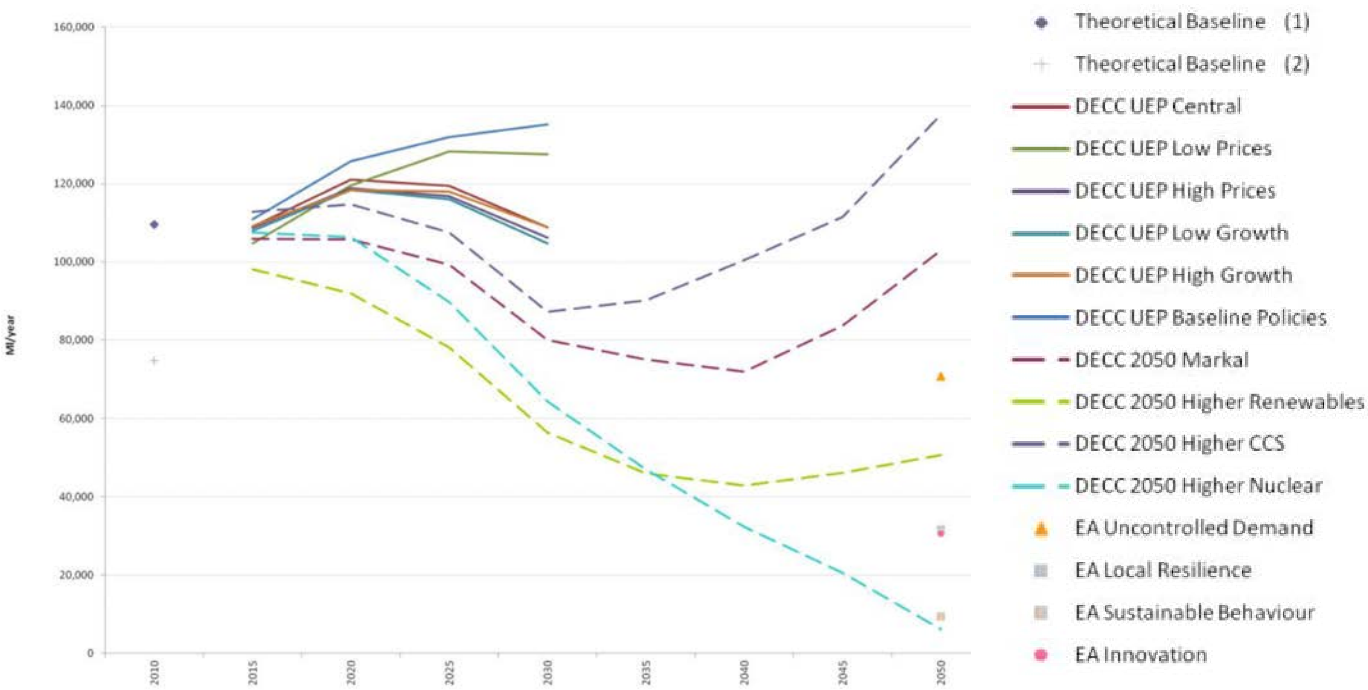
Changes to energy generation in the future may increase demand for freshwater in some locations. Some scenarios of the future energy mix suggest a wider deployment of technologies that are relatively water-intensive, such as carbon capture and storage (CCS). Plants fitted with carbon capture consume from 44% to 84% more water per unit of power than traditional fossil fuel fired power stations, due to an increase in cooling and process uses[67].The Government has stated that:

> *CCS has a critical role to play in reducing emissions in the UK… CCS is also the only technology available to substantially reduce emissions from certain industrial processes. The government wants to see CCS deployed at scale in the 2020s, competing on cost with other low-carbon technologies.*[68]

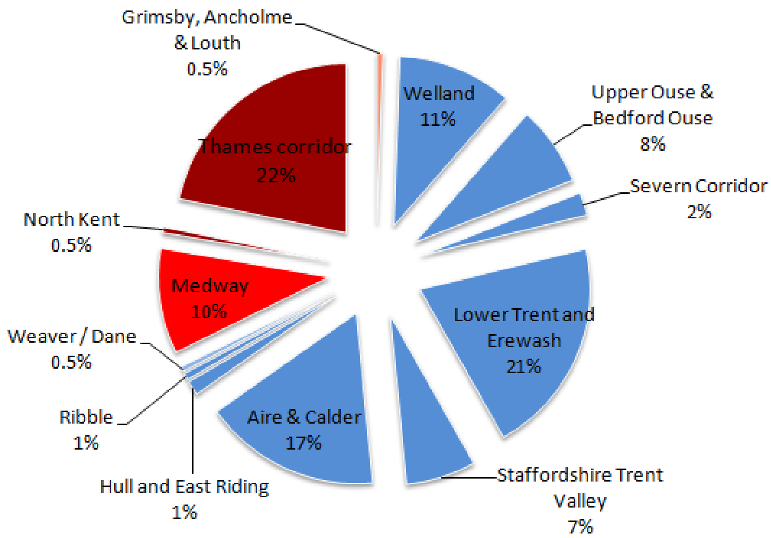
The Case for Change report considered a range of energy futures and showed that in the short-term we might expect an increase of around 27 Ml/d by 2030 but in the longer term most scenarios showed a fall by 2050s, with the total range of forecasts falling between +13 to -370 Ml/d.

Total freshwater demand (excl. hydropower) under modelled scenarios[69]

[66] *ibid*
[67] Adaptation sub-committee – Progress report – Managing climate risks, 2014. P74
[68] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/381859/Top_40_Annex_FINAL.pdf
[69] Environment Agency, Forecasting future water demand by the electricity generation sector, 2014 p16



The Environment Agency found that 4 of the 13 power stations that use freshwater are in catchments identified in Abstraction Licensing Strategies as having insufficient water available at lower flows[70]. The following pie chart shows the catchments in which these power stations are located.

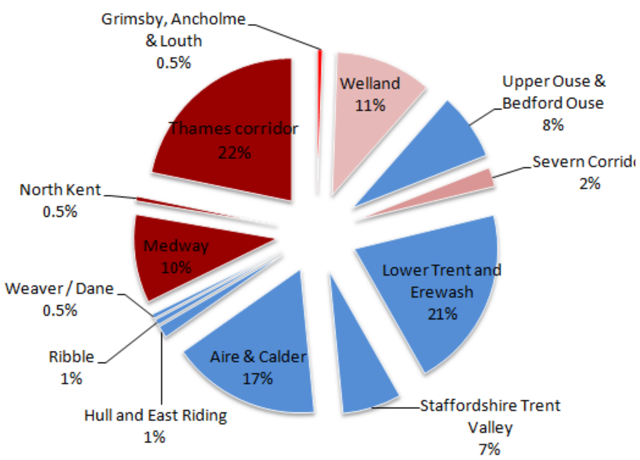


Availability of water for the environment & abstraction –	% range
Water available	0-100 % sufficient water
No water available	100% to 124% Insufficient water
No water available	125% to 149% Insufficient water
No water available	150% to 199% Insufficient water
No water available	>200% Insufficient water

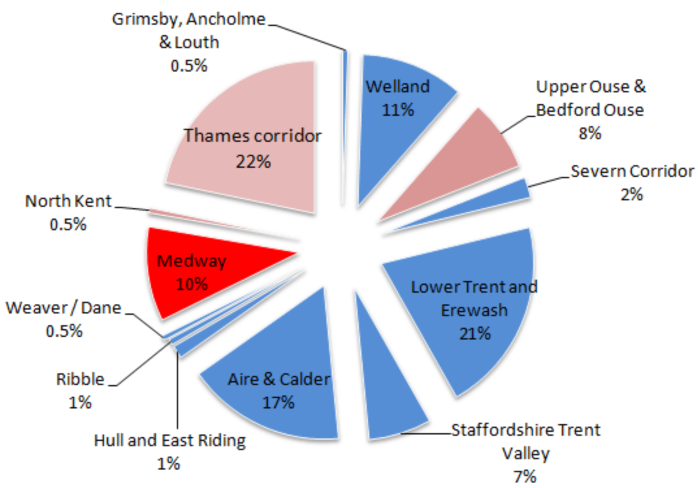
[70] Environment Agency – Internal briefing, Current and future electricity generation in freshwater catchments, 2014

The work considered what would happen if electricity production increased under a range of scenarios. As can be seen from the pie charts below, under the Uncontrolled demand scenario, six catchments were then classified as having no water available, whereas under the Sustainable behaviour scenario the situation remained approximately the same[71].

Uncontrolled Demand (2050)



Sustainable Behaviour (2050)



The Environment Agency's forecasting of future water demand by the electricity sector concluded that future demand for freshwater were variable – they could increase or decrease depending on the future electricity generation mix, including the uptake of CCS, future location and the cooling technology used[72].

Agriculture

Current demand

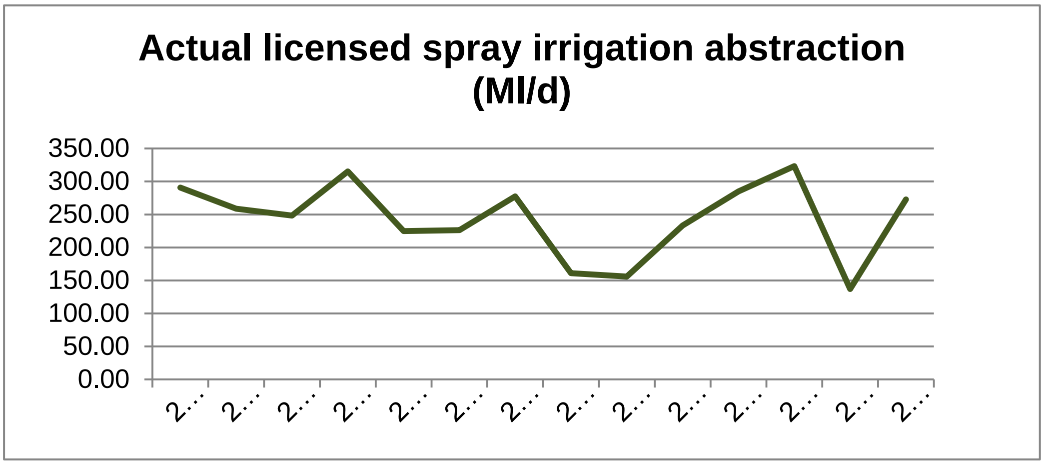
Current agricultural abstraction is around 350 Ml/d[73][74]. While this is not a large proportion of the total abstraction, it is likely to be concentrated at times when water is less available and therefore in some catchments it is locally significant. It should also be noted that 55-60% of total agricultural water use is from mains, rather than directly abstracted water[75].

Within the agricultural sector, water is used for a range of activities such as irrigating nursery and field crops, watering livestock, and washing down machinery. Approximately 40% of total agricultural water use is by livestock enterprises, with drinking water for livestock accounting for approximately 200 Ml/d. A further 40% (approximately 200 Ml/d) is used for irrigating field crops such as potatoes and vegetables. The remaining 20% of water is used in the nursery crop sector[76].

[71] Environment Agency – Internal briefing, Current and future electricity generation in freshwater catchments, 2014
[72] Environment Agency, Forecasting future water demand by the electricity generation sector, 2014 p22

[73] ASC Progress Report – Managing the land in a changing climate change, 2013
[74] Environment Agency, Case for Change states baseline agricultural use is 375Ml/d.
[75] ASC Progress Report – Managing the land in a changing climate change, 2013, p24
[76] URS, Optimal Water Allocation, Interim Report, 2013 p19

Weatherhead and Knox[77] estimated that demand for irrigation water, corrected for weather variation, grew at an underlying average rate of 2% per year between 1982 and 2005. Recent abstraction data, shown in the graph below, for spray irrigation shows that abstraction varies markedly from year to year, and is higher in drier years.



WRAP estimated from 2011 data that the agricultural sector uses approximately 11% of non-household public water supply[78]. This is backed up by water companies' forecasts in their WRMP, which show that it is a relatively minor component, although locally important in some water resources zones[79].

Future forecasts

Agriculture in England in the UK is likely to be less affected by climate change than other countries at lower latitudes as small rises in temperature can be beneficial for agricultural production, water is not limiting[80]. The adaptation sub-committee progress report (2013) stated that:

'Higher temperatures, increased production and less summer rainfall could create a supply demand imbalance [in agricultural demand] of between 45-115 billion litres [120-315 Ml/d] in a dry year in the next 10-20 years[81].'

In the UK, irrigation is generally a supplement to rainfall. Many farmers apply less irrigation water than the calculated crop demand because of equipment or water resource constraints, or as a deliberate policy to maximise profit. [82] Various approaches have been developed to simulate future irrigation demand and as with other sectors, irrigation forecasts are highly sensitive to the prevailing socio-economic conditions[83].

Forecasting future water demand for agriculture is therefore complex, and any forecasts are going to be subject to large uncertainty. The Case for Change work indicated that agriculture was one of the largest areas of future uncertainty - its forecast of agricultural use ranged from a baseline of 375 Ml/d to 475 Ml/d for the Local resilience scenario to 1000 Ml/d under the Uncontrolled demand scenario.

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[77] Knox J, Weatherhead E K & Rodriguez-Diaz J A (2008) Assessing optimum irrigation water use: additional agricultural and non-agricultural sectors. Environment Agency Science Report - SC040008/SR1.

[78] WRAP- Freshwater use in the UK: Agricultural Sector, 2011, p5.
[79] Agricultural demand makes up 15% of South East Water non-household demand (45% in one WRZ) and 3.5% of Southern Water's non-household demand.
[80] Adaptation sub-committee, Progress Report 2013, p20
[81] This is equivalent to 123-315 Ml/d.
[82] Watts *et al*. A climate change report card for water – Working technical paper, 2013 p17
[83] Adaptation sub-committee, Progress Report 2013

A House of Commons report[84] into climate change and agriculture highlighted that there may be an issue of water availability for agriculture in southern, eastern and central England. The report had medium confidence that spray irrigation demand in England and Wales would change by between -10% and +80% by the 2050s and between -4% and +110% by the 2080s, although baselines and projections varied significantly depending on region.

Case for Change agricultural demand scenario assumptions for 2050 (Ml/d)

Baseline	Innovation	Uncontrolled demand	Sustainable behaviour	Local resilience
	Lots of choice in smart technology at low cost. High water use efficiency	Farming becomes more intensive. Increase in water use because of expectations of high quality	People adapt to climate change. Farmers are subsidised to do so efficiency widely practised	Significant increase in area under cereal/vegetable crops. Lack of available innovation technology to reduce water demand.
375	950	1000	725	475

Collaboration

There are some examples of agricultural interests collaborating. A UKIA report illustrates 6 examples of such collaboration; most are based in East Anglia[85].

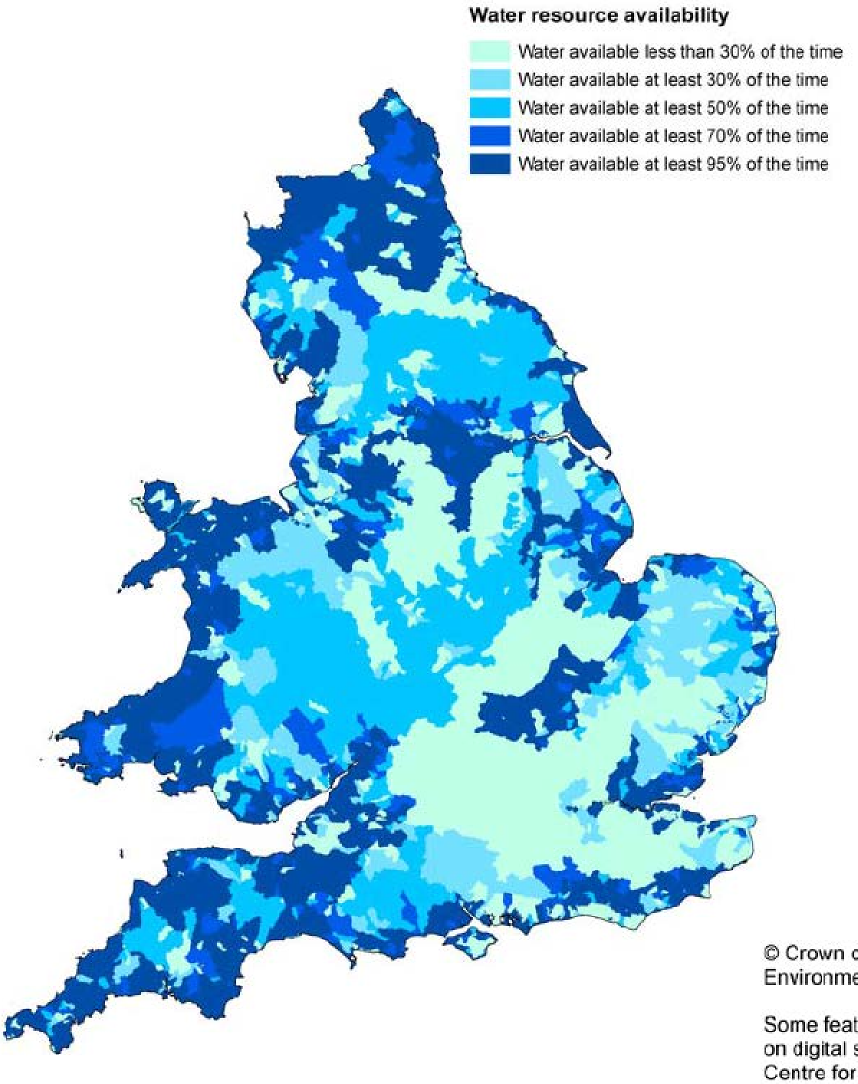
One example is the Lincoln Water Transfer which formed in 2000, emerging from collaboration between the Environment Agency, the Upper Witham Internal Drainage Board and the local National Farmers Union. The group holds a single abstraction licence and allocates the water collectively according to agreed upon protocols. The arrangements allow members to abstract from 25km of drainage channels and irrigate the 4,600ha of land defined on the licence, thereby allowing flexibility of water and land use[86].

[84] House of Commons, Agriculture and Climate Change, (Christopher Barclay), 2012
[85] UKIA, Working together to protect water rights, 2011
[86] *Ibid*

5. Annex 5 – Water availability

Current situation

Our rivers and groundwater resources are highly managed. The Case for Change work highlighted that water availability is greatly restricted across large parts of England and Wales, as can be seen in the map below.



Water resource reliability: percentage of time water would be available for abstraction for new licences.

The Water Framework Directive requires member states to achieve protected area objectives, aim to achieve good ecological status (or potential) and good groundwater quantitative status by 2015 and prevent deterioration in the status (or potential) of water bodies.

We are currently carrying out investigations into whether existing abstractions are damaging protected sites; affecting river flows or causing poor groundwater quantitative status, and are taking action to remediate damage where possible. This involves collecting evidence on abstraction impacts, assessing all of the options to resolve the problem and agreeing with the abstractors involved on the best course of action. This may lead to changes to abstraction licences, and the way water is managed, although solutions to look at mitigating any damage are also considered.

The AECOM report[87] highlighted that the minimum flows needed to meet good ecological status under the Water Framework Directive could be around 2000 and 4000 Ml/d in England. This is the equivalent of 14-28% of all public water supply in 2015 in England. However, it is important to note that this includes rivers where it may not be technically possible, or cost-beneficial to achieve good status.

Climate change

Changes to water availability

Our current understanding of the impact of climate change on water resources in England is based on the latest UK Climate Projections (UKCP09).

Watts et al.[88] reviewed a number of academic papers for trends in water availability. While there is some variation, they concluded that summer flows are likely to decrease[89].

The Case for Change[90] reported the changes in mean river flow between the baseline and 2050s for the 4 seasons for 11 climate model simulations. The overall pattern is varied, reflecting the complex nature of UK weather patterns and uncertainty in the impact of climate change. The seasonal summary below shows the range of scenario results:

> In winter (December, January, February) there is a mixed picture in England and Wales with drier, similar or wetter patterns, all within +40 per cent to -20 per cent change.
> In spring (March, April, May) more of the scenarios are drier for most of the UK, with decreases of up to 44 per cent. However, for four scenarios central England has increased flows (up to 40 per cent).
> In summer (June, July, August) scenarios predominantly show decreases in runoff throughout the UK, ranging from +20 per cent to -80 per cent. The largest percentage decreases are mainly in the north and west of the UK although the range between scenarios is large (0 to 80 per cent).
> In autumn (September, October, November) there is a mixed pattern with a wide range of percentage changes (+60 to -80 per cent) across the UK. Most scenarios indicate decreases in flows, especially in the south and east (up to -80 per cent) whilst in the west and north changes are small. One scenario shows no change or an increase in runoff across the UK[91].

The picture for groundwater is still unclear. Early results suggest that in some climate scenarios increased winter rainfall leads to increased recharge and higher groundwater levels that persist into the summer but in others recharge reduces, leading to lower groundwater levels and reduced availability of groundwater for abstraction.

Droughts

There is considerable uncertainty regarding how likely we are to experience droughts in the future. Watts et al. (2013) states that climate change models are not good at representing the processes that lead to the persistence of extended dry weather across northern Europe.

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87 AECOM, Strategic Water Infrastructure and resilience, March 2015
88 Watts *et al*. A climate change report card for water – Working technical paper, 2013
89 Watts *et al*. A climate change report card for water – Working technical paper, 2013 p14
90 Environment Agency, Case for Change, 2013 p19
91 Environment Agency, Case for Change, 2013 p19

Blenkinsop and Fowler considered precipitation-deficit droughts in six different Regional Climate Models (RCMs) for the 2080s. Short summer droughts are projected to increase in England and Wales, though these results are uncertain. Changes in longer droughts are even more uncertain. The longest droughts are projected to become shorter and less severe in most of the RCMs. Blenkinsop and Fowler caution that climate models may not be able to simulate persistent low rainfall events, making it difficult to draw conclusions about long droughts[92].

In an apparently contradictory finding, Vidal and Wade (2009) use a slightly different definition of precipitation deficit drought, and find an increase in long droughts in south east England by the end of the century. Vidal and Wade agree with Blenkinsop and Fowler (2007) that uncertainty is great, and that water supply planners need to consider a range of possible future droughts.

Burke et al. (2010) look at droughts from 3 to 18 months duration and find an overall increase in droughts of all duration through the 21st century; though with a wide spread that spans decreases as well as increases in drought frequency. As an example, the possible frequency of a drought like 1976 by the end of the 21st century could range from the current frequency (perhaps 1 in 100) to 1 in 10 years (Burke et al. 2010)[93].

[92] Watts *et al*. A climate change report card for water – Working technical paper, 2013 p14
[93] Watts *et al*. A climate change report card for water – Working technical paper, 2013 p14

Annex 6 – Non-drought reasons for public water supply failure

Water resources resilience is a much wider issue than just resilience to lack of rainfall. Looking at recent history, it is other hazards such as flooding and cold-weather which have meant taps have run dry in recent years.

The UKWIR resilience good practice guide[94] lists 43 non-drought hazards as a check list for company resilience planning, grouped under the following headings:

Weather and climate
Procurement and staffing
Pollution
Physical damage
Societal
Communications and power
Geological processes
Miscellaneous

The guide states that flooding, drought, extreme cold spells and climate change are the 'primary' resilience drivers that the industry needs to address. The AECOM report[95] also highlights water quality issues such as waste fires, herbicide spills, metaldehyde and other pollution to rivers and groundwater.

This section provides an overview of some of these risks and highlights where we need further evidence. This section tends to focus on public water supply issues as there is a lack of understanding and evidence of non-water company supply hazards.

Flooding

Flooding (coastal, surface and/or groundwater) can cause widespread disruption to infrastructure. For example, the flooding of Severn Trent Water's Mythe treatment works near Tewkesbury in 2007 left 350,000 people without potable water for between 7-10 days[96]. At the peak of the incident the company deployed in excess of 1,400 bowsers to over 1,100 locations which represented the largest number of bowsers used in a single incident in the United Kingdom. Severn Trent estimated the cost of this incident was between £25-35 million.[97]

More recently, flooding in 2014 caused issues for a number of water companies. For example, floodwater at Sutton and East Surrey's Kenley treatment works risked supplies to 116,000 people[98].

Weather extremes

High summer temperatures can cause an increase in demand which can lead to shortages, particularly in single source supply areas.

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[94] UKWIR, Resilience planning: Good practice guide – summary report, 2013, p7
[95] AECOM, Strategic Water Infrastructure and resilience, March 2015
[96] Ofwat, Resilient Supplies, Nov 2010, p6
[97] Severn Trent Water (no date) Gloucester 2007 The impact of the July Floods on the Water Infrastructure and Customer Service. Final Report. Available from http://www.stwater.co.uk p38
[98] http://www.waterplc.com/pages/news/press-releases/article222-kenley-water-treatment-works-is-operating-normally/

Freeze-thaw can also be a major contributor to leakage, which in turn can cause water shortages. For example, frozen ground followed by a rapid thaw in Northern Ireland in December 2010 led to around 40,000 households without potable water for up to 12 days[99].

Pollution and water quality

Water quality issues can cause a range of hazards for water companies. From algal blooms in reservoirs, to herbicide spills, the quality of water can cause issues for treatment and meeting water quality standards.

Diffuse pollution from cryptosporidium, metaldehyde and nitrate have all caused outage or loss of deployable output for a number of companies such as Sutton and East Surrey Water, Anglian Water and Southern Water.

Point source pollution such as from contaminated land or spills into river may also affect deployable output. Historic industrial pollution has caused long-term issues for companies such as Affinity Water, Southern Water and Thames Water. Companies that rely on river sources are also at risk of pollution from spills, for example Severn Trent Water and South Staffordshire Water are companies that have river sources with limited storage.

Power supply

Power failure can cause issues for pumping and treatment of water.

Asset failure

Infrastructure or engineering failure may cause risk to supply. Leaks from reservoirs, deteriorating assets and burst pipes may cause temporary reductions to supply. A recent example is a burst pipe into Affinity Water's Egham water treatment works which disrupted water supplies to a large number of customers in July 2015[100].

Conclusions from review of the non-drought failures

Large scale, short to medium length, disruptions in supply in the last decade have had a number of causes. Given the magnitude of some of the failures, we would recommend that any assessment of resilience should include non-drought hazards. Given the variety of causes of non-drought failure, an approach such as that advocated by Butler (2015), looking at the consequences, rather than the causes of failure might be appropriate[101].

[99] http://www.bbc.co.uk/news/uk-northern-ireland-12094518 (accessed May 2015)
[100] https://www.affinitywater.co.uk/where-we-are-working.aspx?wID=2256 Accessed 21 August 2015
[101] Butler, *Preparing for the unimaginable*, presentation at WRMP24 workshop, March 2015

Annex 7 – Current level of public water supply risk

Water companies plan to a ‘level of service’. This is the planned average risk of restrictions that its customers will face. For example, customer temporary use restrictions may have a planned average level of service of 10% risk in any one year, whereas, a drought order restricting non-essential uses might be in the region of a 2.5% risk in any one year. The 2012 Water resources planning guideline stated that companies should ‘should engage customers in key decisions when formulating its plan, and find out what levels of service customers expect through research and communication with its customers.’ The role of customers is therefore critical in determining the level of service.

As the level of service is an agreement between a company and its customers, there is considerable variation nationally (see table below). These are presented in the format water companies use, ie 1 year in 10 equals 10% risk in any one year.

Water Company	Temporary use restrictions	Drought order for non-essential use	Emergency drought order (reducing demand): rota cuts and standpipes
Affinity Water	1 in 10	1 in 40	1 in 120
Anglian Water	1 in 10	1 in 40	1 in 100
Bournemouth Water	1 in 20	Not stated	Not stated
Bristol Water	< 1 in 15	< 1 in 33	< 1 in 100
Cambridge Water	1 in 20	1 in 50	1 in 100
Essex and Suffolk Water	1 in 20	1 in 50	
Northumbrian Water	Never	Never	Never
Portsmouth Water	1 in 20	1 in 80	1 in 300
Severn Trent Water	< 3 in 100	< 3 in 100	Unacceptable
South East Water	1 in 10	1 in 40	Included as Emergency planning action in drought plan
South Staffs Water	1 in 40	1 in 89 (simulated period)	Unacceptable
South West Water	1 in 20	1 in 40	Unacceptable
Southern Water	1 in 10	1 in 20	Civil Emergency

Sutton and East Surrey Water	1 in 10	1 in 20	Extremely rare (not in historic record)
Thames Water	1 in 20	1 in 20	Never
United Utilities	1 in 20	1 in 35	Unacceptable
Wessex Water	1 in 30	Not specified[102]	Never
Yorkshire Water	1 in 25	1 in 80	1 in 500

It is also important to note that companies have a limited amount of data on which to base their levels of service. For example, if a company states that it will never use an emergency drought order, this is likely to mean that it will not need this restriction if the historic period is repeated. The historic period is typically around 100 years. Therefore, there is risk that the company will need this restriction if there is a drought which is beyond the severity of one in recent history.

Some companies (e.g. Southern Water) are considering stochastically derived drought sequences to try and be more robust in the calculation of their levels of service.

It is also important to note that deployable output evidence at the extremes of operation, i.e. drought, is subject to uncertainty, and is often reliant on expert judgement.

[102] In Wessex Water's drought plan, NEU is grouped with TUBS, although TUBS are the primary action. No further frequency information is included in the drought plan.

Annex 8 – Strategic infrastructure options

The AECOM report[103] provided a brief analysis of option types and their relative advantages and disadvantages. This section provides a brief overview of some of the option types most likely to be considered for new options.

Desalination

Desalination provides resilience to severe and extreme droughts, floods and temperature extremes. However, it is limited to coastal and estuarine locations, and has high operational energy demands that can result in high carbon emissions. Desalination could enhance the resilience of the environment to drought by diverting abstraction away from conventional surface and groundwater sources. In the future, if energy and treatment constraints can be addressed, desalination may become a more economic, continuous and flexible source of water, rather than a source only used as a last resort.

Water reuse

Direct water re-use has similar benefits and constraints to desalination, although it is not geographically constrained. At present there is effectively a 'presumption against' direct effluent reuse in the UK for potable supplies due to perceived higher health risk. Indirect reuse is seen as more acceptable (due to the perceived dilution and mixing properties of rivers) and occurs throughout England on an unplanned basis.

Effluent reuse could result in less effluent being discharged to rivers, reducing flows, and downstream environmental and water supply resilience. Effluent reuse is likely to have most benefit in coastal areas where water would otherwise be lost to the sea. Indirect reuse increases treatment costs as both discharge and abstraction must be treated.

Storage

Reservoirs provide resilience in shorter term droughts (two years or less dependent on design) and they can enhance environmental resilience through the controlled release of water to rivers. However, they are vulnerable to longer term droughts.

Transfers

Transfers are likely to have a fundamental role in enhancing the resilience of water supplies, especially when combined with other option types that are resilient to drought, such as desalination. Transfers may be either through improved regional connectivity between water company networks, or as a national canal or pipeline transfer scheme. Greater connectivity is generally good for overcoming drought, flood and water quality outages.

The environmental impacts of river and canal transfers need to be examined on a case by case basis. Most will have risks associated with transfer of invasive species and fish disease; and the ecology of receiving waters may be affected by changes to water quality and sudden changes to flow.

Demand management

Leakage reduction, metering and water efficiency are sensible resilience measures as they reduce our demand for water. They also help to achieve environmental resilience as they reduce the requirement for abstraction, helping to preserve river flows in a drought

[103] AECOM, Strategic Water Infrastructure and resilience, March 2015

Barriers to progress on strategic infrastructure and resilience

We have not undertaken any research on the perceived as barriers to increasing resilience, however, we believe the following might be potential barriers:

- Single-sector planning processes do not sufficiently incentivise multi-sector investment in new infrastructure

- Lack of specific regulatory incentive to increase resilience and unclear expectations between companies, regulators and government

- Evidence around extreme events is uncertain and therefore it is difficult to justify expenditure

- Lack of suitable metrics to define and measure resilience

Annex 9 – National Policy Statement

A National Policy Statement (NPS) sets out Government policy for the provision of major infrastructure. It is used by the decision maker as the primary basis for deciding development consent applications for developments that fall within the definition of Nationally Significant Infrastructure Projects (NSIP) as defined in the Planning Act 2008. A NPS sets out:

- How the project will contribute to sustainable development
- How the objectives have been integrated with other government policies
- How actual and projected capacity and demand have been taken into account
- Relevant issues in relation to safety or technology
- Circumstances where it would be particularly important to address the adverse impacts of development.
- Specific locations, where appropriate, in order to provide a clear framework for investment and planning decisions.

NPS's undergo public consultation and parliamentary scrutiny, before being designated (i.e. published). The NPS is kept under review by the Secretary of State.[104]

The legislation[105] sets out the following conditions for water infrastructure to be included in NPS:

- A **dam or reservoir** in England, constructed by one or more water undertakers with a storage exceeding 10 million cubic meters.
- **Alteration of a dam or reservoir** in England by one or more water undertakers with additional storage that is expected to exceed 10 million cubic meters
- **Transfer of water** by a water undertaker in England expected to exceed 100 million cubic meters a year between either:
    - River basins
    - Water undertaker areas
    - A river basin and a water undertaker

There are currently no options in companies' water resources management plans that would meet the NSIP criteria. However, it should be noted that Thames Water is currently reviewing the best strategic options to meet a deficit in London. It has provisionally selected an effluent reuse plant but states that it will undertake further work on the three main contenders before coming to a final decision in its next water resources management plan. The three options it is considering further are effluent reuse, a transfer from the River Severn and an Upper Thames Reservoir. The Upper Thames reservoir would be large enough to be classified as a Nationally Significant Infrastructure Project. The Severn Thames transfer probably would not be, unless it was supported by a new reservoir at Longdon Marsh.

Water companies tend not to publish the size of their feasible options, instead stating how much water they will provide. There is not a straightforward relationship between the deployable output of a reservoir and its size. However, if a reservoir has a deployable output of over 20 Ml/d it may well be large enough to qualify under the NPS if it was selected as a

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[104] http://www.legislation.gov.uk/ukpga/2008/29/part/2

[105] http://www.legislation.gov.uk/ukpga/2008/29/part/3/crossheading/water/england/2009-01-26?view=plain

preferred option in a future plan. The feasible reservoir options in water companies' current water resources management plans that are over 20 Ml/d are listed in the following table. Note none of these are preferred options currently.

Water company	Option	Deployable output
Anglian Water	Grafham Dam Raising	40Ml/d
Anglian Water	Norwich Storage	46Ml/d
Anglian Water	New Rutherford	26Ml/d
Portsmouth Water	Havant Thicket	24Ml/d
Thames Water	Longworth	63/101 Ml/d
Thames Water	Chinnor	151/201 Ml/d
Thames Water	Longdon Marsh and Severn Thames transfer	207 Ml/d
Thames Water	Upper Thames Reservoir	63/101/151/201/242/283 Ml/d
United Utilities	Haweswater	22 Ml/d
United Utilities	Borrowbeck	80 Ml/d

We note that the definition of the NPS currently excludes any feasible transfers. It also limits the NPS to water undertakers which might cause an issue if a collaboration between water undertakers and other sectors was to occur.

Annex 10 - Drought restrictions

Temporary Use Bans

The use of temporary use bans is governed by a code of practice[106], which sets out good practice principles and actions for water companies in England and Wales to follow when they are evaluating whether and how to implement water restrictions.

Activities restricted by a TUB can include:

- Watering a 'garden'[107] using a hosepipe
- Cleaning a private motor-vehicle using a hosepipe
- Watering plants on domestic or other non-commercial premises using a hosepipe
- Cleaning a private leisure boat using a hosepipe
- Filling or maintaining a domestic swimming or paddling pool
- Drawing water, using a hosepipe, for domestic use
- Filling or maintaining a domestic pond using a hosepipe
- Filling or maintaining an ornamental fountain
- Cleaning walls, or windows, of domestic premises using a hosepipe
- Cleaning paths or patios using a hosepipe
- Cleaning other artificial outdoor surfaces using a hosepipe

NERA work for Thames Water indicated that household willingness to pay to avoid a TUB was 10p a day.

Drought orders

Under the Water Resources Act 1991[108], an ordinary drought order can be implemented by either water companies or the Environment Agency in a drought situation. Among other actions, it gives either body the right to prohibit or limit particular uses of water under the Drought Direction 2011 for up to six months, with the possibility of extension for up to a further six months.

Drought orders extend the range of activities restricted under a TUB. Water companies can prohibit the following commercial activities:

- Watering outdoor plants on commercial premises;
- Filling or maintaining a non-domestic swimming pool or paddling pool
- Filling or maintaining a pond (excluding those being used to rear aquatic life)
- Operating a mechanical vehicle washer
- Cleaning a vehicle, boat, aircraft or railway rolling stock
- Cleaning non-domestic premises (exterior)
- Cleaning non-domestic windows
- Cleaning industrial plant

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[106] Water UK and UKWIR (2014), Code of practice and guidance for water companies on water use restrictions – 2013
[107] Under the TUB legislation, a garden includes: a park; gardens open to the public; a lawn; a grass verge; an area of grass used for sport and recreation; an allotment garden; any area of an allotment used for non-commercial purposes; any other green space. It does not include agricultural land; land used commercially (i.e. for growing); a temporary garden or flower display; and plants that are in an outdoor pot or in the ground, under cover.
[108] WRA 1991 Section 74

- Suppressing dust
- Operating cisterns (unoccupied buildings)

Vivid *et al*[109]*.* found that an ordinary drought order implemented by a water company could be expected to have the greatest impact on strawberry growers, golf courses, wholesale and retail nurseries, landscaping services, non-domestic swimming pools, window cleaners and commercial car washes, with the impacts ranging from 25% to 100% of the sector's Gross Value Added (GVA). GVA data for strawberry growers and commercial car washes is unavailable but excluding those two sectors the total GVA of the sectors listed above was estimated by Vivid *et al.* (2013) to be £6.6bn in England in 2010.[110]

Emergency drought orders

The key differences between an ordinary and emergency drought order are:

- An emergency drought order gives the authorised water company the power to specify restrictions on water use, in addition to those uses listed in the Drought Direction 2011
- It can also give the water company permission to set up standpipes, implement rota cuts or to use water tankers for the provision of potable water
- Emergency drought orders authorised to either a water company or the EA can only be implemented for a maximum period of three months, with one possible extension of two months.

Emergency drought orders have not been implemented in the UK since 1976. In late-1995, under conditions of intensifying drought, Yorkshire Water successfully applied for an emergency drought order to apply rota cuts to domestic supply (i.e. to provide a piped supply for 24 hours out of every 48), introduce pressure management and install standpipes. Although rota cuts were not implemented, water was transported to the region by water tankers to maintain supply.

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[109] Vivid Economics, Halcrow, Cranfield University and the Centre for Ecology and Hydrology. (2013) *The impacts of drought in England: Final report prepared for Defra*. March 2013
[110] AECOM, Strategic Water Infrastructure and resilience – Annex C, p 15

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