Climate Change Adaption Report

2021

bristolwater.co.uk

Executive Summary

Bristol Water supplies 1.2 million customers who depend on us every day to provide clean drinking water to their tap. This essential service utilises our most important natural resource. We collect water, store it, treat it to industry leading standards and deliver it to our customers' taps. We've been doing this successfully for 175 years.

We recognise that our role in society goes well beyond the business transaction of supplying water. It is impossible to disconnect what we do from caring for the environment and protecting it for our future. It's a daily focus for us and is deeply embedded into how we run our business. Whether our focus is on protecting local water catchments, increasing biodiversity or on reducing our carbon impact, it's always at the forefront of the decisions which we make.

In 2018 we made history being the first water company to formalise our view of our role within society through our social purpose and our industry leading social contract. Our purpose is ***to have a positive impact on our customers, communities, employees and the environment***. Our social contract provides a means of prioritising our actions and reporting on performance, allowing our stakeholders to hold us to account.

The business of water supply can be significantly affected by climate change and we are already noticing its impacts. This is the second assessment of climate change risk that we have carried out: following our first assessment in 2011 we invested in significant changes to our infrastructure and systems to increase their resilience and ensure that we can continue to provide a reliable supply of high-quality water to our customers in the face of climate change.

The science of climate change continues to develop and the water industry has played a leading role in this. We will continue to engage in this process and will continue to review our vulnerability to the impacts of climate change – and although we anticipate that there may be less water available from the environment in the future, the investment we have made and the flexible nature of our supply system means that we are confident we can continue to meet our customers' needs in the future.

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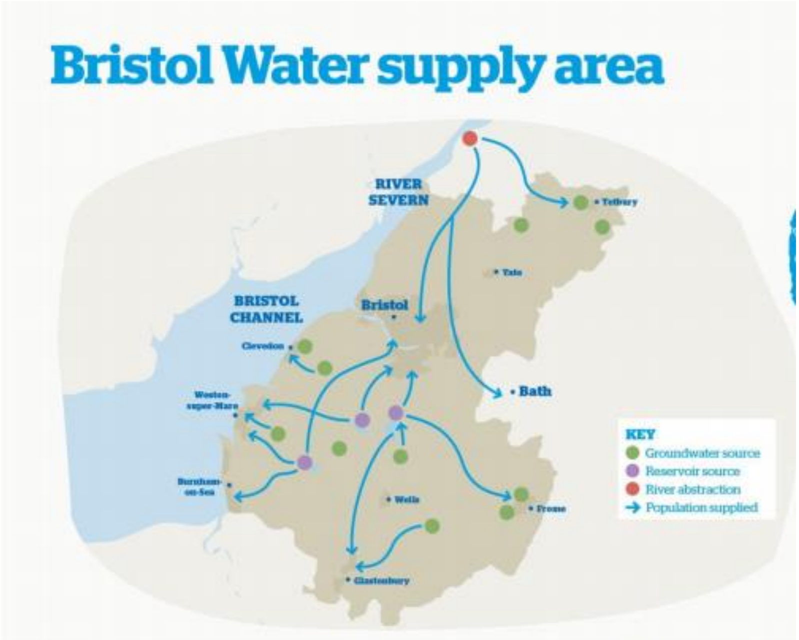
1.1 About us

Bristol Water is the oldest water company in continuous operation in the UK, and one of the oldest in the world, among the pioneers developing the science of modern water supply and treatment. We've been serving our customers for 175 years.

Today we supply water to 1.2 million customers in an area of 2,400 square kilometres, which stretches well beyond our birthplace of Bristol. Wessex Water provides the sewerage services in our area, and together we provide one joint bill to our customers.



Around half of our supply comes from reservoirs in the Mendips, with smaller groundwater abstractions around our supply area. The rest comes from the River Severn via the Gloucester and Sharpness Canal. We have a highly interconnected network of treatment works, pipes, pumps, and service reservoirs to get the water to the tap, and this connected system with its various sources of water gives us a great deal of flexibility and resilience in how we supply our customers.

We are pleased to see climate change receiving a greater level of attention and interest, both from the general public and governments across the world – COP26 helped increase focus on the need both to reduce carbon emissions and to adapt to the reality of climate change, and we continue our work to address both of these issues through our own Net Zero Routemap[1] and assessment of the actions needed to adapt to a changing world.

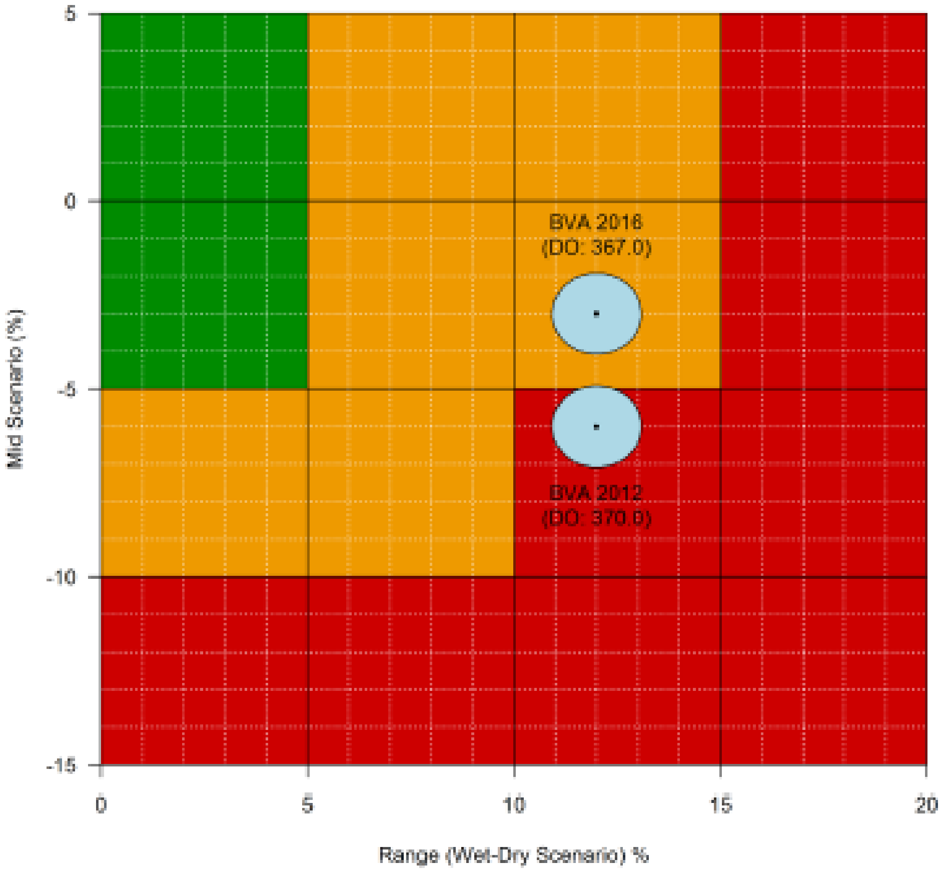
[1] Bristol Water Net Zero Routemap https://f.hubspotusercontent30.net/hubfs/7850638/Our%20Routemap%20to%20Net%20Zero%20Carbon%20by%202030.pdf

1.2 Climate change projections

Our climate change vulnerability assessment in our 2011 report was 'High'. In updating this report we have now identified that the vulnerability of the Bristol Water system to climate change is 'Medium'. This is largely due to the nature of our water resources, because these catchments and water sources benefit from the more intense winter rainfall events predicted in a changed climate.

We recognise that prediction of climate change impact is still uncertain, so we need to keep forecast impacts under review. Despite only having a Medium vulnerability we have used a detailed assessment of the impact in order to understand it as fully as current science allows.

Figure 1: Magnitude versus sensitivity plot for Bristol Water for the 2030s[2]



[2] HR Wallingford, Bristol Water WRMP 2019 Climate Change Assessment - Appendix

1.3 Works since 2011 CCA report

In our 2011 report, we identified several large schemes that would reduce future risks to customers from the impact of climate change.

1.3.1 Tetbury resilience scheme

This is a water transfer system to support the town of Tetbury in the Cotswold Hills, which has historically been dependent on a single water source in the town. The scheme has been completed and is operational.

1.3.2 Southern Resilience Scheme

We have made significant investment in our network in the form of the Southern Resilience Scheme, which has provided improved security of supply to over 280,000 customers across our supply area including Weston-Super-Mare, Cheddar, Burnham-on-Sea and Glastonbury and the southern part of Bristol. This strengthened network gives us increased flexibility and allows us to move water from our northern sources into our southern region in the event of a loss of supply, or back up to Bristol if required. The scheme has been completed and is operational.

1.3.3 Oldford support

This is a water storage and transfer system which allows water from the Mendip Lakes to be used to support the supply to the town of Frome, which has historically been more dependent on local borehole supplies. The scheme has been completed and is operational.

1.3.4 Flood risk mitigation

Flood defences have been installed at two key sites where modelling indicated that the sites could be vulnerable to surface flooding. The scheme has been completed and is operational.

1.3.5 Glastonbury to Street support

During flooding in 2014 on the Somerset levels we experienced a burst main due to ground movement during the flood. This occurred in an area of the network where there are 2 parallel mains but we identified that some areas without dual mains are susceptible to the same risk. This scheme will provide a new main to Glastonbury following a different route to increase the resilience of supply to this area. The scheme is in planning stage and will be operational by 2025.

2 Business Planning

Long term and emergency and contingency planning is covered by a variety of internal strategic plans, statutory plans and site or event specific risk assessments. The main documents in the hierarchy of risk management with respect to climate change impacts are set below.

- An internal high level wide ranging business risk register
- Statutory Water Resources Management Plan 2019
- The Periodic Review Final Business Plan (FBP)
- A flood risk analysis for critical installations
- A dam break and overflow risk analysis

These documents incorporate a significant element of both baseline and long term climate change risk planning. The links with long-term climate change is more formally expressed in some documents than others: climate change risk assessment is carried out in great detail in the Water Resources Plan process and this can be seen through the link[3] below.

2.1 Business Risk Register

The Business Risk Register is a strategic-level internal document documenting a range of financial, operational, regulatory, environmental and security risks. In some instances site-specific risks are also recorded when an individual asset is of particular importance e.g. flooding risks to critical plant or loss of supply of critical chemicals. Climate change is included in this high level document with an impact score that ranks the potential business impacts alongside risks such as financial failure, regulatory issues and health pandemic. The risk register is reviewed every year to capture emerging risks and reassess existing risks.

[3] https://f.hubspotusercontent30.net/hubfs/7850638/Site%20Assets/Offline%20docs/Bristol-Water-Final-WRMP-2019-August-2019-REDACTED.pdf

2.2 Water Resource Management Plan

Our Water Resources Management Plan (WRMP) was submitted to DEFRA in 2018. This statutory document covers the period 2020 to 2045 and sets out in detail the issues impacting the availability of water and the demand for water in that period, together with actions to mitigate adverse impacts. The WRMP is a long-term component of business planning informing the Strategic Business Plan and 5 yearly investment cycle. The WRMP analysis sets out a 25-year projection of the supply/demand position taking into account the impact of a basket of risks as set out below:

Impact of climate change projection on water resources
Impact of climate change projection on water consumption
Population and housing growth
Commercial and economic growth
Changes in water consumption patterns
Impact on greenhouse gas emissions

The purpose of the analysis is to ensure there is a long-term plan in place that will maintain customer levels of service. One of the most significant parameters is the availability of water. The impact of the climate change projections used in our analysis forecast a reduction in availability of water over time.

The outcome of the WRMP is an investment plan comprising a basket of operating and engineering measures to maintain the supply demand/balance over time. This is to ensure that customers will not be subject to an increased risk of restrictions water use over the 25-year period. The approach analyses a wide variety of possible options and takes into account externalities such as the social and economic costs of leakage, water efficiency and greenhouse gas emissions.

We have complied with a prescribed methodology for producing the WRMP. The Environment Agency has set out the methodology for the analysis of climate change, the consideration of future consumption and overarching approach. Ofwat has set out economic parameters such as the social and economic level of leakage and the economic method to balance supply and demand. DEFRA has set out the level of public consultation required and has controlling oversight of the plan through such directions as may be issued by the Secretary of State.

The performance of the company in respect of its WRMP is monitored annually through the regulatory June Return process. This is to ensure that outcomes from the agreed investment programme set out in the Final Business Plan are delivered and are providing customer benefits. The statutory annual update also records any material changes in outturns or assumptions that may affect the WRMP. The statutory process for producing a WRMP is repeated every 5 years as part of the business planning process and Periodic Review.

2.3 Final Business Plan

The Final Business Plan (FBP) defines the key areas of investment in the company assets over a 5-year period. This investment requirement is partially defined by the WRMP and is intended to be consistent over the short term with the least cost options to maintain the supply demand balance identified in the WRMP. The common areas between the plans include:

- Investment for reduction in demand from water efficiency measures
- Investment in water metering to reduce consumption
- Investment for reduction in leakage to social and economic levels
- Investment in existing resources and new resources to improve availability of water

The FBP addresses other wider business priorities including:

- Resilience and security of supply networks, pumps and reservoirs
- Resilience of treatment works and processes
- Maintenance of major structures such as dams and impounding reservoirs

Some of the thinking behind the resilience and security schemes in the FBP is driven by the need to address impacts of current probabilities of extreme meteorological events (high temperatures, flooding, and heavy rainfall, etc.). These events may also arise from future climate change. Therefore we have already proposed adaptation to some climate change risks as a consequence of our planning process. The extent to which these future events become more frequent and/or more severe or cross a management threshold is one of the key uncertainties in the current methodology.

2.4 Flood Risk Analysis

Where the loss of an asset is not readily mitigated by use of alternative supplies or plant, a high overall service risk was assigned. A further detailed investigation was then carried out for those sites with a high or medium service risk. This work was carried out internally and by consultants. Proposals for remedial measures were established for the two most vulnerable sites identified for implementation during AMP5.

The following assets were considered in detail:

- Water sources
- Treatment works
- Pumping and booster stations
- Service reservoirs

2.5 Dam Overflow and Failure Risk Analysis

We have 15 large reservoirs that are subject the statutory requirements of the 1975 Reservoirs Act. Three of these are treated water storage reservoirs and two minor raw water storage reservoirs. The remaining ten are large raw water reservoirs, including three pump storage reservoirs, one off-line storage reservoir and six impounding reservoirs.

All structures are managed using the strict regime set out in the Reservoirs Act. We fully comply with the Act, which includes the requirements summarised below:

- Follow supervision, operating and maintenance requirement as advised by DEFRA panel supervising engineer and produce annual condition reports
- Facilitate detailed inspection of structures by DEFRA panel inspecting engineer at 10-year intervals or less if required
- Recording of water levels, depths, overflows and other discharges or incidents
- Recording of dam stability, settlement, masonry condition, cracks and leakages
- Comply with any recommendation from an engineers' report
- Prepare reservoir flood plans as set out in the 2003 Water Act and amended by the Floods and Water Bill 2010

In addition to the production of reservoir flood plans we have carried out a quantitative analysis of the total risk of reservoir failure for individual and combinations of circumstances (QRA). A significant component of this analysis is the quantity of reservoir overflow that may be tolerated without initiating a reservoir failure. The analysis was carried out by external consulting engineers.

For our category 'A' reservoirs where failure could result in loss of life, we have investigated the discharge and overflow capacity in terms of the probable maximum flood risk (PMF). This study confirmed that these structures have an acceptable or low probability of failure at a 0.5 PMF or greater (0.5 PMF estimated to have a 1 in 10,000 year return period).

Although our reservoirs are able to safely handle the 1 in 10,000 year flood discharge or greater without incurring significant risk of failure, the discharge volumes under such circumstances would be likely to cause significant damage downstream and add to problems of severe local flooding. However, in such circumstances the damage would not be compounded by the failure of a reservoir.

In order to establish the impact of climate change on this type of analysis, we would need to fully understand how the frequency or severity of such extreme events may change in future (if at all). A 1 in 100 year overflow event that changes return period to 1 in 50 years due to climate change would not have a material effect on the overall risks as analysed in the QRA.

At the current state of knowledge, the factors of safety in the QRA appear able to encompass an element of climate change risk. This could prove otherwise if it can be clearly shown that return periods of extreme events once in 10,000 years or greater are subject to order of magnitude changes.

3 Climate Change Projections

The key climate parameters we need to consider in terms of potential business risks are:

- Mean maximum temperature of the hottest months of the year
- Changes in minimum winter temperatures
- Amount of winter rainfall
- Amount of summer rainfall
- Changes to average summer/winter temperature
- Amount of sea level rise
- Changes to frequency of extreme rainfall events
- Changes to flooding frequency
- Changes to frequency, severity or duration of drought events

Please see HR Wallingford report "Bristol Water WRMP 19 Climate Change Assessment" in Appendix 1 for full details, a summary below:

Impacts for the 2080s are likely to be significant but not to differ that significantly from those estimated for WRMP 2014 under the 2030a time horizon. When these impacts are scaled back through the WRMP planning horizon as per the WRPG guidance (currently under review), the move to the 2080s is likely to lead to a significant ***reduction*** *in the climate change impacts realised for each year in the planning horizon. The reason is that the average increase per year from the baseline to 2080s is less that that from the baseline to 2030s and reflects the combination of Bristol Water's system characteristics are the* ***"wetter winters/ drier summers"*** *signal in the UKCP09 projections*

3.1 Sea level rise

The UKCIP09 projected sea level rise for the medium emissions scenario is 370mm by 2080. The company has no critical assets close to coastal regions or in areas that would be permanently affected by a one metre increase in average sea level. Additional coastal flooding and permanent flooding of some parts of our supply area may be expected. This would mean that some areas may no longer be suitable for human habitation, and therefore there would be no need for minor distribution infrastructure. We consider the impact of sea level rise for most of the company operations and assets to be negligible, even with the impact of storm surges, compared with more general flooding risks.

Our public water supply intake from the Sharpness canal provides a significant proportion of the company's water resources and if the site was incapacitated for any length of time the consequences for customers in Bristol could be significant without mitigation in place. However, there are already flood protection plans in place for this site to provide protection for the combination of sea level rise and flooding to 2035.

Extreme fluvial and coastal flooding might cause inundation of the canal, which could mean that water supply to two major treatment works is not available for up to three weeks while the flood subsides and the source is flushed with clean water. An unmitigated event of this magnitude could result in a loss of supply to a large population in the north and east of Bristol, at a scale which would not be manageable by the normal means of distributing bottled water or using temporary bowsers. We identified this as a key risk in our 2011 report, and as shown in section (1) we have since carried out a major network upgrade to enable a more resilient transfer of water from other sites, supporting areas which are normally supplied with water from the Sharpness Canal.

The Environment Agency Shoreline Management Programme for the Severn Estuary is a key interdependency. We recognise EA's continuing commitment to maintain adequate defences to protect assets along the Severn Estuary. This will ensure the probability of the most severe flooding remains less than 1 in 200 in any one year and we maintain engagement with the Avonmouth Severnside Economic Area[4] programme of flood defence development to ensure that we remain aware of any significant development in flood defence management in the area.

[4] https://www.asea-flood-ecology.co.uk/

3.2 Temperature

3.2.1 Summer average

Persistent high temperatures during a hotter than average summer already impact a range of business functions. The affected business assets and operations affected are listed below:

- Treatment works performance (filter de-oxygenation, iron and manganese releases, increased production of Bromate and THMs)
- Raw water quality (algal blooms, de-oxygenation, reduced treatability)
- Large seasonal water demand (rapid depletion of reservoirs, water quality problems)
- Increased demand for water (deteriorating supply demand balance)
- Plant operation (overheating of pumps and electronic components)
- Mains network (biofilm, poor treated water quality, taste and odour, higher chlorine requirement)
- Sustained high rates of evapotranspiration and high soil moisture deficits (resulting in delayed recharge and reservoir recovery)

3.2.2 Summer temperatures on hottest days

Very high daily temperatures drive high peak demands for water that can outstrip the capacity of the mains network and treatment work. Other effects are:

- High peak demand for water (low system pressures or no water, inability to maintain service reservoir levels, local or partial supply failures)
- Mains network (depressurisation and poor water quality due to partially full mains)
- Network, plant and treatment works (inadequate capacity, unable to provide volumes)
- Plant operation (overheating, failure and loss of supply to service reservoirs)
- Staff welfare (heatstroke, sunburn)
- Increased water consumption per capita (deteriorating supply demand balance)

3.2.3 Winter average

Periods of very low temperature can cause treatment works to perform poorly as the speed of chemical and biological reactions is reduced. If winters are become warmer, there may be some benefit as some treatment process become slightly more efficient.

However, warmer winters may also lead to differing cropping patterns with changed pesticide and nutrient loading of raw waters. These can be difficult contaminants to remove from water and will cause problems leading to water quality failures and increasing outage of affected sources if the current rate of these events becomes more frequent or intense.

3.2.4 Winter temperature on coldest days

The effects of freezing weather on business operation are summarised below:

- Increase in burst mains
- Increase in overall leakage (minor mains, private supply pipes and customer plumbing systems fail)
- Treatment works performance (increased level of shut downs and quality failures as dosing lines and minor pipework is blocked by ice, difficulty mixing some chemicals in freezing conditions.

From the UKCIP09 data, it is not clear whether the modest degree of winter warming predicted will be sufficient to reduce either the intensity or the frequency of freezing periods.

3.3 Rainfall

3.3.1 Summer average

If the projections are correct, we would expect the following:

- Additional demand for water for discretionary use during dry periods (resulting in higher per capita consumption and lower reservoir levels, impacting supply demand balance)
- Low volume in reservoirs with more frequent algal blooms (water treatment and quality issues, problems with fish kills and loss of recreational use, could compromise SSSI status and Water Framework Directive (WFD) obligations)
- Reduction in deployable output (from delayed recharge, a small effect, but could be significant long-term)
- Environmental impacts due to low river and stream flows (further regulatory reductions in abstraction to meet future Environmental obligations under the Water Framework Directive WFD)
- Increased reliance on winter rainfall and two season criticality resources (requiring a planning approach that captures as much winter water as possible)

3.3.2 Wettest summer day

The Met Office study, 'Changes in the frequency of extreme rainfall events for selected towns and cities' July 2010, suggests that rainfall events with present return periods of 1 in 20 years may increase in frequency to 1 in 12 years by 2040.

The implication is that there may be an increasing frequency of disruptive events

- High volume inflows to reservoirs (possible stability problems with earth dams, higher rates of silt deposition)
- High volume overflows from reservoirs (down river flooding issues or damage to spillways)
- Increased frequency if high turbidity in springs and wells (causing reduced treatment plant output or shutdown to maintain water quality)
- Potential flooding of critical assets (at risk sites have remedial work planned, but the solution may prove inadequate beyond 2040)
- Political pressure to maintain low reservoir levels to absorb flood inflows (if this approach was adopted, there could be substantial reductions in deployable output)
- Rapid runoff causing raw water quality (high nitrates and high pesticides concentration resulting in the need to shut down or reduce plant output)
- Increased frequency of lightning strike events associated with summer storms (causing plant, telemetry, and ICA outage)
- Local pluvial flooding (causing transportation and communication difficulties)

3.3.3 Winter average

The historic winter average rainfall has shown a decreasing trend since the 1960s. This observed downward trend is contrary to the regional UKCP09 projection. This may be a statistically insignificant effect or a local microclimate effect as the historic trend is anomalous when compared to the data at other company gauges. If the historic trend persisted into the future, eventually there could be a marked reduction in reservoir resource yield.

Stored water in the Mendip reservoirs provides approximately 40% of the overall resources mix. Winter rainfall is a key factor in the recharge of the reservoirs and groundwater. At present, we consider our resources position to be two-season critical, that means security of supply is more vulnerable to dry winters than a dry summer. Increasing winter rainfall may improve the rate and scale of recharge, offsetting to some degree a propensity for drier or warmer summers. However, the increase in water consumption from population projections could mean that we become single season critical over time, making wetter winters less of a benefit.

Other impacts include:

- Large variation of inflows to reservoirs (possible stability problems with earth dams, higher rates of silt deposition)
- High volume overflows from reservoirs (down river flooding issues or damage to spillways)
- Raw water quality issues (higher leaching of nitrates phosphates and pesticides resulting in compliance outage of treatment works)

3.3.4 Wettest winter day

The rainfall volume on the wettest days of winter is projected to increase. This change has the potential to increase the probability of winter flooding events and large reservoir overflows. The impacts outlined in the section above would potentially occur more frequently than for summer events.

4 Climate change Impacts

4.1 Water Resource Assets

The highest risk climate change impacts on the future availability and quality of water resources are tabulated below.

WATER RESOURCES Critical assets impacted	Climate change variable	Effect of variable on asset	Effect on stakeholders	Effect on organisation	Probability of outcome	Timescale for risks to materialise	Adaptation actions
Water resources yield from reservoirs	Rainfall change	Reduction in yield, less water available	Decreased security of supply, more frequent use restrictions	Higher costs, regulatory failure	High likelihood of manageable event. Low likelihood of unmanageable event.	Impacts may be occurring now, Material effects within 10–15 years	WRMP twin track demand management and new sources development
Boreholes and wells	Rainfall change	Reduction in yield or levels, less water available -possible failure	Loss of supply some wells are critical for local supply	Higher costs either from emergency measures or Adaptation	High likelihood of manageable event. Low likelihood of unmanageable event.	Impacts may be occurring now, Material effects within 10–15 years	WRMP twin track demand management and new sources development
Reservoir water storage	Intense rainfall and pluvial flooding	High volume overflows	Overflows contributing to local flooding	Regulatory pressure to maintain low levels resulting in loss of yield	If flooding frequent, Floods and Water Act would permit action	10-30 years	Would need to develop new resources
Intakes, wells aqueducts, boreholes	Intense rainfall and pluvial flooding	Rapid infiltration, contamination, treatment failure, quality failure	Loss of service	Higher costs, reduction of water available from increased outage	Can happen now, frequency will increase as rainfall intensifies	Material effects within 10–15 years	Catchment management, may need to improve treatment process
Reservoir water storage and availability	High daily temperatures or high summer temperatures	Higher water demand (PCC) and high evaporative losses	Decreased security of supply, more frequent use restrictions	Higher costs for unusual transfers of water between resources	High likelihood of manageable event. Low likelihood of unmanageable event.	Impacts may be occurring now, Material effects within 10–15 years	WRMP twin track demand management and new sources development

Critical asset impacted	Climate change variable	Effect of variable on asset	Effect on stakeholders	Effect on organisation	Probability of outcome	Timescale for risks to materialise	Adaptation actions
Reservoir water storage and availability	High summer long temperatures	Rapid drawdown, algal blooms de-oxygenation of water with stagnation ecological damage (fish deaths)	Water develops taste and odour problems, loss of recreational amenity value in reservoirs	Higher treatment costs adverse regulatory impacts on SSSI quality	High likelihood of occurrence as these vents take place now and will increase in frequency	Impacts may be occurring now, Material effects within 10–15 years	Will need to monitor, may need changes in operation, treatment works or artificial aeration of reservoirs
Reservoirs, wells and boreholes	Inundation or fluvial flooding	Extreme quality impacts making sources not fit for use (nitrate or metaldehyde, coliforms, etc)	Loss of supply from affected sources until flooding subsides	Higher costs either from emergency measures or adaptation	High likelihood of occurrence but Adaptation in place or planned for some sites	Further effects within 10–15 years	WRMP twin track demand management and flood defence as necessary
Reservoirs, wells and boreholes	Combination effects of high temperature and low rainfall	As identified in rows above	Reduced water in environment and low river flows, WFD compliance issues	Regulatory requirements to reduce water abstraction, loss of abstraction licences	Already occurring for some parts of the UK	Within 20- 40 years	Loss of licenced abstractions would require development of replacement sources

1.1 Treatment works assets and water quality

Treatment works and processes have developed to be able to deal effectively with an historic range of water quality challenges. As drinking water quality standards have changed, processes have been upgraded. Climate change now adds an additional dimension, in that the future deterioration in raw water quality needs to be addressed.

Climate change may impact on the operation of treatment works. Typically we would change or add new treatment process stages as required, or put in place network resilience schemes to ensure dual supplies to maintain customer service. The issue becomes one primarily of increasing operational or capital costs.

The table below sets out the primary risks to water quality and treatment works that could occur as a consequence of climate change.

WATER TREATMENT Critical asset impacted	Climate change variable	Effect of variable on asset	Effect on stakeholders	Effect on organisation	Probability of outcome	Timescale for risks to materialise	Adaptation actions
Treatment works	Temperature	Deterioration in raw water quality	Water not meeting standards or interruption to supply	Regulatory failure, higher costs of operating	High likelihood of occurrence,	Impacts may be occurring now, Material effects within 10–15 years	Resilience schemes to supply affected area from other sources. Change TW process.
Treatment works	Rainfall	Deterioration in raw water quality	Water not meeting standards or interruption to supply	Regulatory failure, higher costs of operating	High likelihood of occurrence,	Impacts may be occurring now, Material effects within 10–15 years	Resilience schemes to supply affected area from other sources. Change TW process.
Treatment works	Intense rainfall and pluvial/fluvial flooding	Outage due to plant shut down	Interruption to supply requiring delivery of alternative water supply	Regulatory failure, higher costs of operating	At risk now frequency may increase in future	Impacts may be occurring now, Material effects within 10–15 years	Resilience schemes to supply affected area from other sources and provide flood defence
Treatment works	Higher temperatures	Outage due to process failure	Water not meeting standards or interruption to supply	Regulatory failure, higher costs of operating	High likelihood of occurrence,	Impacts may be occurring now, Material effects within 10–15 years	Resilience schemes to supply affected area from other sources. Change TW process.

1.2 Treated water network assets and operations

The treated water network includes all pipeline, service reservoir and plant and pumping assets downstream of treatment works.

The table below sets out the primary risks to the treated water network and associated assets that could occur as a consequence of climate change.

WATER NETWORKS Critical asset impacted	Climate change variable	Effect of variable on asset	Effect on stakeholders	Effect on organisation	Probability of outcome	Timescale for risks to materialise	Adaptation actions
Distribution mains	Reduction in summer rainfall drying ground causes increased subsidence, heave and rapid ground movements	Stress on mains joint failures mains failures and increasing leakage	Temporary loss of supply, higher cost in long term if leakage reduction becomes more costly	Regulatory failure from not meeting leakage targets	High likelihood of occurrence	Material effects within 10–15 years, but only observable during hottest years	Increase maintenance and mains replacement
Distribution mains and pumping plant	Reduction in summer rainfall or increase temperature leading to higher demand for water	Demand for water exceeds the capacity of assets in peak demand periods	Loss of service and supply failure	Regulatory failure from not meeting service targets increase in compensation payments	High likelihood of occurrence	Material effects within 10–15 years but only observable during hottest years	Active management of Network
Distribution service reservoirs	High summer or daily temperatures leading to much higher demand for water	Demand for water exceeds the capacity of assets in peak demand periods	Loss of service and supply failure	Regulatory failure from not meeting service targets, increase in compensation payments	May occur in peak periods	Material effects within 10–15 years	Active management of Network
Distribution mains	Higher temperatures	Increased bio film reduced chlorine residuals Increasing MDPE join failures	Risk of contamination taste and odour problems increased complaints	Regulatory failure from not meeting service targets. Increased leakage from new MDPE mains	Probable due to temperature rise, but difficult to see trend at present	Material effects within 10–15 years	Increased mains flushing may be required Network monitoring for regulatory targets

4.2 Company wide operations

In addition to the direct effect of climate change on company assets, we have assessed the risk to the following business operations:

- Short term environmental damage of dry periods
- Increased subsidence or damage to structures during dry periods
- Transportation difficulty during flooding events
- Loss of SCADA, ICA signals
- Climatic effects on staff in extreme weather

Most of the operations are not considered very high risk items as the consequences in terms of customer and business impacts are relatively short term or minor, or the risks have been mitigated already.

4.3 Third party interdependency

The day-to-day operation of the business is dependent on others to provide goods and services. These external operations will also be impacted by climate change (and be best placed to develop their individual strategy to address those impacts). The key organisational interdependencies we have identified are:

- Supply/availability of treatment chemicals during extreme weather
- Security of electricity supply to major treatment works
- Resilience of communication networks
- Resilience of third party assets (flood defences, watercourses and pumps)

4.3.1 Power supply and distribution

The smaller sources, operating depots and treatment works have automated on site generation in case a failure of the grid supply.

Of our six large treatment works, five have dual grid supplies. The largest site has a power requirement in excess of 1 MW and does have a dual power incomer, but both are from a single substation at Walham near Gloucester. This power supply infrastructure was almost flooded during 2007 and subsequently flood defences have been installed at the substation site. We have also installed large scale gas fired generation at our own treatment works which in an extreme situation could be used to provide electrical resilience to the site.

Since 2011 we have invested extensively in interconnecting our supply network in order to minimise the number of customers dependent on a single asset. As a result our supply system is now resilient to all but the largest scale power outages.

4.3.2 Water treatment chemicals

We aim to hold minimum stocks of all required chemicals of at least 14 days. Stock levels are automatically and manually monitored, triggering orders from suppliers at pre determined levels. Where possible, we have set up dual contractor supplies to ensure continuity of supply should one party be unable to deliver. One significant development since our previous plan has been Brexit, where water companies across the UK have collaborated to ensure a consistent and resilient supply chain for key chemicals. This process has been highly successful and has been further tested through the COVID-19 pandemic, and as a result we believe that our treatment chemical supply chain can now be considered resilient.

4.3.3 Communications networks and providers

For critical and large company sites we maintain independent dual networked communication by both landline and microwave. Smaller operating sites may have a backup system via radio link, or may default to local control and in the worst instance are designed to fail-safe (essentially shut down until manually re-set). The communications hubs are designed to automatically switch in the event of failure.

In the case of a wider public telecommunications failure, the company operates with both cell-phone and landline networks. Should these two systems fail, a low band radio system is available. Although this has limited capacity, it will provide basic communications in the event of a severe emergency such as flooding that may disable part of the public network.

4.3.4 Sharpness supply

We are also dependent on the following large-scale infrastructure:

- The Severn Estuary flood defences maintained and operated by the Environment Agency
- The River Severn Clywedog and Shropshire groundwater transfers operated by the Environment Agency
- The Gloucester and Sharpness canal and pumping stations at Gloucester owned and operated by Canal and River Trust

We have planning and level of service agreements with Canal and River Trust to ensure that the risks of operation of the canal are minimised with respect to water abstraction. This agreement includes emergency repair and pumping arrangements to the canal and associated infrastructure in the case of structural failure of this asset.

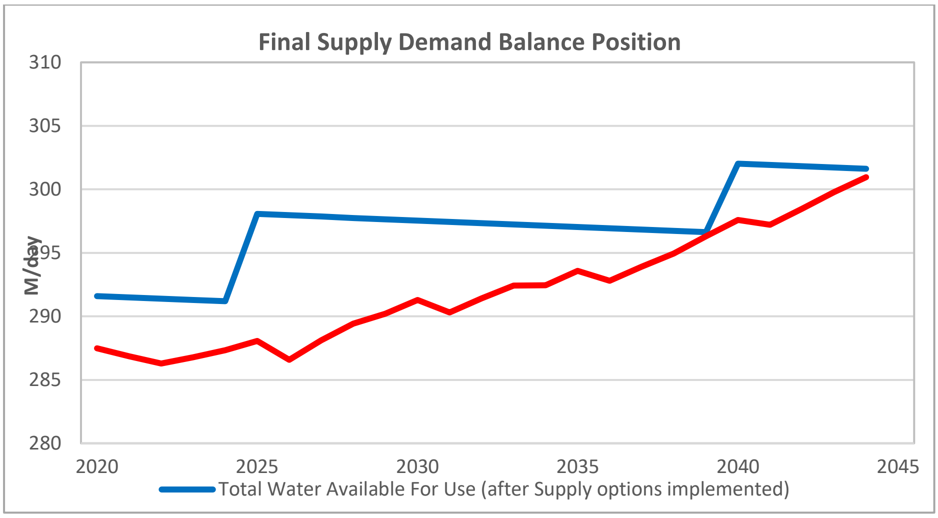
5 Climate Change Adaptation Actions

5.1 Supply demand balance[5]

In order to provide a resilient supply to our customers, we need to ensure a balance between available water (supply) and the water needed (demand) - this is known as the supply demand balance and is the underlying principle behind our Water Resource Management Plan (WRMP). The WRMP develops options to ensure we meet this balance for at least 25 years into the future, with the process repeated every five years to ensure we always have a plan based on the best information available. Our preferred approach in WRMP19 is focused on leakage reduction activities to achieve a 15% reduction in leakage by the end of 2025, with further reduction in leakage planned and work to reduce losses from some of our larger "raw" water mains (these are used for untreated water being transferred from lakes and reservoirs).

Further activities in our plan include reducing our bulk export to Wessex Water, continuing to actively promote our free meter option programme and to meter households on change of occupier, and enhancing our water efficiency activities to complement our metering programme to reduce average dry year per capita consumption. This planned programme of activity means that even in the face of climate change and population growth our supply demand balance remains positive for the next twenty five years as shown below.

Figure 2: Final Supply Demand Balance Position



[5] https://f.hubspotusercontent30.net/hubfs/7850638/Site%20Assets/Offline%20docs/Bristol-Water-Final-WRMP-2019-August-2019-REDACTED.pdf

6 Conclusion

In our 2011 adaptation report we identified key actions needed to increase the resilience of our business to climate change. We have now completed the majority of these actions and as a result our system is now significantly more flexible and operationally resilient than it was ten years ago.

Since this time we have experienced two significant tests to our system management: Brexit and COVID-19. In the face of both of these challenges we have maintained a resilient supply of high quality water to all our customers and at no point we needed to impose supply restrictions of any kind.

We engage deeply in the developing science of climate change, and due to the nature of our resource system we have now determined that the medium-term impact of climate change is less severe than was anticipated in 2011. As our preparedness for climate change has improved, and our vulnerability has reduced, we are pleased to conclude that we will be able to continue to provide our customers with the service they have come to expect over the last 175 years.

7 Appendix