Bristol Water
Final Water Resources Management Plan 2019

August 2019

Document Control Sheet

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Contents

A set of Appendices (A-J) are published alongside this plan, see **Section 2.4**. This is supported by a range of technical documents which are available by request.

1 Executive Summary

This is Bristol Water's final Water Resource Management Plan (WRMP19), updated with various revisions taking account of the feedback we received on our consultation on the draft version of the plan during March to May 2018. It presents our approach to the management of water resources for the benefit of our customers, the wider community and the environment in the period 2020 to 2045. The plan proposes the most affordable programme of action to ensure that we can provide a reliable and resilient supply of water to our customers, even in the face of severe drought. Customer preferences have been included in every phase of the development of the Plan, with over 12,000 customer surveys carried out ranging from simple annual surveys to detailed whole-day customer workshops; and the process of development for our draft Plan has included collaborative discussions with other water companies through new and existing partnerships such as the West Country Water Resources Group and the River Severn Working Group.

The Bristol Water Board has full ownership of this plan, which has been developed under a formal process of external assurance and review. The WRMP19 is closely linked with the findings of our process to develop our Drought Plan (published in 2018). The programme of water resource management actions identified in the WRMP19 has also been used in the development of our Business Plan for the 2019 Price Review (PR19) - a plan which includes our investment proposals for the next five year period (2020-2025) along with proposed research and investigations to refine and develop our WRMP approach in future years.

Development of WRMP19 has been informed by the structured guidance issued by the Environment Agency (EA), and formal pre-consultation meetings have been held with EA and other key stakeholders to test the development of the plan in order to ensure that it takes a proportionate and evidence-based approach to the management of water resources in our supply area.

We regard the provision of safe, high-quality drinking water as our top priority in planning for the service we provide and none of the options in our preferred plan would lead to any deterioration in water quality. In addition, our proposals for options which might need to be implemented in various different scenarios would also allow for provision of safe high-quality drinking water with no deterioration from the high standards that our customers rightly expect.

Bristol is a rapidly developing area and the population in the Bristol Water supply area is projected to grow during the period 2020-2045 from approximately 1.2 million people to approximately 1.5 million. However, thanks to ongoing improvements in domestic water efficiency and a projected increase in water metering, we do not forecast a large increase in overall demand for water during this period. Similarly, although we anticipate that climate change will reduce the water we have available for public water supply, the integrated nature of our supply network and the range of water sources we have available both help to mitigate this impact. We therefore anticipate that the impact of climate change on the water available for use in our area over the next 25 years at least is likely to be relatively low.

As a result of this position, we anticipate that changes in the demand for water can be addressed in the short to medium-term by further reducing our already low levels of leakage, an action that will further increase our resilience to drought. This is an area that our customers have told us they consider a very high priority, and this has been reinforced in the responses we received as part of our draft WRMP19 consultation. We plan to reduce leakage by 15% by 2025 as detailed in this WRMP19. In the longer term, we have also confirmed that we can address any future deficit in the planning period to 2045 through further leakage reductions as well as a reduction in losses on raw water systems.

Our WRMP19 differs from the previous 2014 plan (WRMP14) in the following ways:

- We have not made any specific allowance for large new non-household water supply, although we have included the possibility of this in our modelling of other scenarios.

- This WRMP plans for a 1 in 200 year severe drought instead of against the design drought of 1943/1944, which is less severe than the 1 in 200 year drought. For the WRMP19, we have tested our drought planning approach using an innovative computer-generated set of "synthetic droughts" in order to ensure that our plan is tested against droughts more severe than those seen in the historic record and that we can continue to supply water without severe restrictions, even in a drought so severe that it might be seen only once every two hundred years.

- Our approach on Headroom now includes an updated approach to risk, with increased acceptance of risk across the duration of the planning period to 2045, in line with current best practice for water resource planning.

- Our approach on climate change modelling follows the latest water industry and EA guidance, which in the case of Bristol Water indicates there will be a slightly lower projected impact of climate change on the resilience of our supply than was the case in WRMP14.

- The outcome of these changes are:

    - Bristol Water faces a minor supply deficit from 2035, largely driven by a growing population in our supply area.

    - The baseline supply deficit in 2035 is 0.87 Ml/day, gradually rising to 9.18 Ml/day by 2045 (end of AMP11). Our options appraisal work indicates that demand management options such as reduction in leakage, reduction in raw water losses and increased household metering alongside further water efficiency activities can fully address this deficit at a lower cost than implementing new water resources. Agreed reductions to the bulk water supply export to Wessex Water after 2025 will also contribute an additional reliable supply of 6.97 Ml/day for Bristol Water's customers to our baseline supply forecast.

Our preferred approach to maintaining the supply-demand balance is therefore focused on optimising the use of our existing water sources while continuing to drive down leakage and water consumption to achieve a more sustainable use of water resources. This accords vey well with the consultation feedback on our draft WRMP19 and reflects strong customer support for this approach as evidenced by our WRMP19 customer engagement activity. In particular, there was strong feedback from customers, our regulators and stakeholders that we should be more ambitious on our plans to reduce leakage and water consumption.

In response, we now plan to deliver a 15% reduction in leakage by the end of 2025 (to 36.5 Ml/day) and to further reduce leakage in the longer term to 35.0 Ml/day by 2035. Our revised leakage reduction programme meets Ofwat's challenge to water companies on leakage and aligns with the policy recommendations set out in the recent (April 2018) National Infrastructure Commission Report on future water infrastructure needs.

We have also strengthened our commitment to reduce water consumption over the next 25 years. This includes increased household metering allied to further water efficiency activities to work towards our long-term aspiration of reducing average per capita consumption to 110 litres/person/day by 2050. We plan to increase household metering from 66% of properties in 2020 to 87% by 2045. Together with additional water efficiency actions, we forecast that average per capita consumption will reduce from 141.6 to 129.4 litres/person/day between 2020 and 2045.

This leaves a 15% gap to our 110 litre/head/day aspirational target for 2050. Closing this gap will require collaborative working with other water companies and local authorities as well as action by government over the coming years to:

- Influence customer consumption behaviour to become more water efficient
- Modify government policy to better support water efficiency actions, such as mandatory water labelling, more water efficiency standards for water using appliances and enhanced water efficiency requirements for new homes
- Incentivise manufacturers and innovators to reduce water consumption rates for household and commercial water using appliances.

We have already instigated the creation of the Resource West partnership with Bristol City Council, University of West of England (UWE) and other organisations to enhance the promotion of water efficiency in our supply area, and we will also work with neighbouring water companies through the West Country Water Resources group on water efficiency promotion.

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Water resource planning is an ongoing process. Although we identify in this WRMP a clear preferred programme of work for the period 2020 to 2025, plans for the long-term period to 2045 are more likely to be subject to change. In order to ensure that our future planning continues to use the best evidence possible and that we continue to provide a resilient water supply service to our customers that allows for change and economic growth in the area we supply, this WRMP19 identifies further investigations and research which are included in our PR19 business plan to ensure we have the information and capacity to maintain a robust long-term planning process.

In 2017 we worked with regional partners to create the West Country Water Resources Group. The principal aims of this group are to undertake regional water resource planning to identify optimal integrated solutions for the region and, in particular, explore new water trading opportunities for the West Country and beyond. Future work of the West Country Water Resources Group will focus on these opportunities and development of a regional plan that will inform the development of our Water Resources Management Plan for 2024. This work will also include widening the group membership to non-water company sectors and helping the publication of information to promote future water markets.

Additionally over the next five years we will continue to seek further innovation and data-sharing opportunities including development of best practice water management options with our customers, stakeholders and other water companies in our region. This approach will also involve working with a wider range of stakeholders than we have engaged in the past, to look beyond water as an isolated issue and bring it into a more central role as a keystone principle in our aspiration to drive affordability and resource efficiency initiatives around energy, environment, health and social resilience.

Assurance of our Water Resources Management Plan

WRMP regulations (Water Resources Management Plan (England) Direction 2017) requires our plan to include assurance from our Board that they are satisfied the plan represents the most cost effective and sustainable long term solution for water resource management. Third-party assurance of the processes and data used in production of a WRMP is not a regulatory requirement, but represents good practice.

Development of the WRMP rightly receives close attention from regulators and other stakeholders and we have followed a structured process of formal and targeted pre-engagement meetings, especially with key representatives from the Environment Agency, to discuss the methodology and data used for each technical section of the plan. This extensive pre-engagement programme provided the opportunity for challenge and clarification on all the technical aspects of our WRMP. While we consider that assurance on the WRMP is our own responsibility and that discussion and engagement with stakeholders does not constitute an assurance process in its own right, we have found it to be an extremely useful and helpful part of our work to ensure that our plan is robust and meets all the relevant legal requirements and guidance.

Our assurance of the draft WRMP and this WRMP has been carried out in tandem with our development of a wider Assurance Framework for our PR19 Business Plan, which has followed a three-tier "lines of defence" approach of operational, internal and independent assurance. The assurance of the WRMP has been integrated with our PR19 Business Plan governance and there has been active Board engagement throughout the plan development.

The WRMP19 has been developed by an expert practitioner-level WRMP working group, which together with its executive team sponsor, formed the basis of our first-line operational assurance. A second line of internal assurance has involved review and challenge from members of our executive team not directly involved in the production of the WRMP, providing a critical review of the plan and reporting to our internal WRMP steering group.

The WRMP has also been subject to independent assurance in order to provide confirmation that it meets the requirements of the extensive best practice guidance on WRMP development and that it provides the most cost effective and sustainable way to manage water resources in the long term. Specialists from Atkins consultants have been commissioned since July 2017 to provide this structured programme of assurance, targeting the technical aspects of the plan. The specialists engaged in this assurance process have experience in both delivering and assessing WRMPs across the water industry. Atkins have carried out a comprehensive assurance review of the data, methodologies and assessments that underpin the WRMP19.

WRMP aspects assured by Atkins:

- Methods and processes to assess supply, demand, risk and investment appraisal, and whether these methods met the criteria of the relevant guidance and best practice reports. The review covered the principles, inputs and outputs for all the relevant models used in the WRMP.

- The nature of the outputs in comparison with previous plans and in comparison with Ofwat and EA expectations.

- Final table outputs, checked against the models and processes described above and against the EA reporting guidance.

- As the process of customer consultation does not constitute a technical process area of WRMP development, formal guidance on customer consultation is not available in the same way as specific technical areas such as demand forecasting, climate change projections or headroom. This aspect of our work to develop the WRMP has not been subject to assurance by Atkins in the same way as the technical aspects of the plan, although it has been challenged and tested through our Customer Challenge Panel.

Atkins concluded that except where specifically noted in their report, Bristol Water has collated its submission in accordance with the Water Resources Planning Guidelines and the associated UK Water Industry Research (UKWIR) guidance notes. Atkins have confirmed that the technical approaches used generally comply with standard water industry practice to a level that is appropriate for the relatively low level of investment proposed within the WRMP19.

We have addressed the issues identified by Atkins in its assurance report for the draft WRMP19, which centred on our leakage cost-benefit data, the assessment of drought resilience and our programme optimisation modelling approach. These areas for improvement or clarification were considered by Atkins as “unlikely to materially affect the draft plan”. The technical assurance of the WRMP19 undertaken by Atkins concluded that updates made since the draft WRMP19 resulted in all areas being rated as “not judged to be material or no issues”.

Bristol Water's Board, having taken account of our internal and external assurance conclusions and its review of the plan at key stages of its development, therefore confirms that it is satisfied that the WRMP represents the most cost effective and sustainable long term solution for water resource management.

The text from Atkins's assurance statement for the WRMP19 is provided on the following page and the assurance report is provided as **Appendix A**.

Assurance Statement for Bristol Water's Water Resource Management Plan

Based upon our audits of Bristol Water's Water Resources Management Plan (WRMP) 2019 technical components and the supporting information we saw over a programme of audits during May to August 2018 (See Appendix A.), we conclude that for the reporting of areas we covered, other than where indicated otherwise in our report:

- at a component level the various teams compiling the documents and information had a reasonable understanding of and were following industry best practice;
- the Company has applied sufficient processes and systems of control to meet its reporting obligations;
- the Company's explanations of where and why it is not following industry best practice are soundly based;
- the Company has sufficient processes and internal systems in place to identify, manage and review its reporting risks; and
- the Company's explanations of how it will manage and/or mitigate material or potentially material reporting risks are soundly based.

Our overall impression from our audits was that the process of preparing Bristol Water's WRMP19 and the supporting information was generally based upon the application of technical approaches that comply with standard water industry practice to a level that is appropriate to the relatively low level of investment that is proposed within the WRMP. Our assessment is based upon the Company implementing its processes as explained to us at the time of the audits.

During the assurance activities, we have had free access to the people responsible for preparing and reporting the WRMP19 technical components and the supporting information.

Jonathan P Archer
Regulation Director
Reporter providing Technical Assurance Services to Bristol Water

2 Introduction

2.1 Background

This is Bristol Water's Water Resources Management Plan 2019 (WRMP19). It sets out how, with the active participation of our customers we propose to ensure that there is a sufficient supply of water to meet the demand forecast from all our customers over the 25-year planning period from 2020 to 2045. It is one of the core business planning tools that we use to drive our business, and links strongly to our Business Plan, our Drought Plan, and our annual operations planning.

We made changes to the plan taking account of the feedback we received on the consultation on our draft plan that took place between 8th March and 31st May 2018. A revised set of WRMP19 regulatory reporting tables accompany this plan.

It describes in detail the technical assessments we have carried out to determine the water that will be available for supply over the 25 year period, and the anticipated customer demand for water over this time; the supply demand balance. This is a technical document and presents all the analysis required by our regulators and Government to support our proposed strategy for maintaining a continued affordable and resilient supply of water to our customers, whilst maintaining the level of service our customers expect from us. We identify and set out our proposals for managing the balance of supply and customer demand, and the options we have considered in determining our preferred plan, including demand reduction measures, optimising the use of our existing water resources, water transfers from outside our supply area and/or developing new water resources within our supply area.

All water companies in England and Wales must produce a WRMP and update it every five years (see **Section 2.2** for details of the regulatory framework). We last published a WRMP in June 2014. During 2017 and 2018 we have reviewed and updated the plan in order to submit the plan to the Secretary of State for approval to publish the new WRMP19 during 2019. As part of the development of our WRMP19 we have carried out extensive engagement with our customers to understand their preferences and priorities (**Section 3**) and sought their views, and those of regulators and stakeholders, through the public consultation on the draft WRMP19 during the period 8th March until 31st May 2018. We have carefully considered the feedback we received on the draft plan and have made changes to this WRMP as a result of comments received. Further details of our consultation process are provided in **Section 3**.

Each WRMP builds on the last one by updating and reviewing the assessments to reflect the latest information, technology, regulatory guidance and the views of our customers and stakeholders. This means that although any options identified for implementation over the first five years of the planning period, from 2020 to 2025 (during AMP7) are very likely to be put in place and planned though the Price Review process. Any options identified for later years may be subject to change in terms of timing and/or option solution, as further detailed investigations are carried out to inform future reviews and updates of our WRMP. This dynamic planning process therefore enables water companies to respond and adapt to the ever evolving water resource position in terms of environment, demographics, and regulatory process. The linkages of the WRMP to the Business Plan is shown in **Figure 2-1**

Figure 2-1: Road Map for the 2019 Business Plan.

2.1.1 Changes and improvements since WRMP14

Several changes and improvements have been made to our WRMP since our published 2014 WRMP. These changes have been made to reflect the latest Defra and Environment Agency water resource planning guidance, and to adopt updated water industry-led research relating to the technical methods and approaches used to develop the WRMP (UKWIR

2016, *WRMP19 Methods*). There have also been a number of national research projects on drought and water resources (Water UK, September 2016, Environment Agency, December 2015). Bristol Water has been closely involved in many of the industry water resource planning research projects and these have been taken into account in updating our WRMP. Since the draft WRMP19 was published, the National Infrastructure Commission has issued its report on securing future water supply resilience for England which contains several key policy recommendations that we have taken into consideration in preparing this final WRMP19. Ofwat has also challenged the water companies to achieve at least a 15% reduction in leakage by 2025.

The key changes to the WRMP19 compared to our 2014 WRMP are detailed in **Table 2-1**.

Table 2-1: Changes to our WRMP since WRMP14

Item	Change from WRMP14 to WRMP19	Approximate impact of change on future deficit
Deployable output	We are now planning for a 1 in 200 year drought event – this reduces the amount of water we assume to be available. This approach is compliant with latest EA guidance.	Increases potential future deficit by 21Ml/day if no other changes to the plan
Headroom	WRMP19 will use a variable (increasing) risk profile across the planning period. This is compliant with EA guidance and is their preferred approach	Reduces potential future deficit by 18Ml/day if no other changes to the plan
Climate Change	Planning approach updated in line with new EA Guidance. This indicates a lower impact of climate change on our resource profile than in WRMP14	Reduces potential future deficit by 12Ml/day if no other changes to the plan
Leakage and losses	We have re-assessed our leakage reduction targets in light of the changes to the supply-demand forecasts, Ofwat's challenge to the water industry, the National Infrastructure Commission's recommendations on future leakage reduction targets, and feedback from our customer engagement research. We have also carried out additional assessment of our raw water losses which has identified scope for further reduction to help increase Water Available for Use.	Proposed leakage reduction to 36.5 Ml/d by 2025 to reduce potential future deficit by 12.5 Ml/d if no other changes to the plan. We also plan to further reduce leakage in the longer term to 35.0 Ml/d by 2045 to reduce the potential deficit by 14 Ml/d if no other changes to the plan. Proposed reductions to raw water losses from 2040 to reduce potential deficit by a

Item	Change from WRMP14 to WRMP19	Approximate impact of change on future deficit
		further 5.5 Ml/d.
Demand assumptions	The proposals for a potential new power station considered as part of the 2014 WRMP. No large industrial demand is included in the baseline calculation and SSE plc (formerly Scottish and Southern Energy plc.) has been advised that this demand is not being included in our planning. A full assessment of future demand has been carried out using micro-component analysis (**Section 7**)	Reduces potential future deficit by 41Ml/day if no other changes to the plan

2.2 Regulatory Framework

WRMPs are produced as part of a statutory process. Under Section 37 of the Water Industry Act 1991 (WIA), water companies are required to provide domestic and non-domestic customers with a reliable supply of water for domestic and business purposes. The Water Act 2003 amended the WIA 1991 by introducing a statutory requirement for water companies to produce WRMPs at least every five years, setting out how we ensure that we are able to meet the demand for water that we expect will arise in the future (WIA 1991 Section 37A, as amended). This legislation also requires us to consult with customers and stakeholders on our WRMP (WIA 1991 Section 37B, as amended).

When producing this WRMP, reference has been made to the following guidance and legislation.

- *Water Industry Act 1991, sections 37A – 37D, as amended by the Water Act 2003*
- *Water Resource Management Plan Regulations 2007*
- *Water Resource Management Plan (England) Direction 2017*
- *Water Resources Planning Guideline: Interim update (July 2018)*
- *Guiding principles for water resources planning: For water companies operating wholly or mainly in England (Defra (May 2016)*
- *Strategic Environmental Assessment Directive (2001/42/EC)*
- *Habitats and Wild Birds Directives(92/42/EEC and 2009/147/EA)*
- *Water Framework Directive(2000/ 60 / EC)*
- *The Eels (England and Wales) Regulations 2009*
- *EU Regulation (1143/2014) on invasive alien (non-native) species (2015)*
- *Water Industry Strategic Environmental Requirements (WISER), Environment Agency and Natural England, October 2017*
- *The government's strategic priorities and objectives for Ofwat (SPS), September 2017*
- *The Water Industry National Environment Programme (WINEP2) issued to Bristol Water September 2017*
- *The Water Supply (Water Quality) Regulations 2016*
- *National Infrastructure Commission report recommendations 2018*

Additional detailed technical guidance and methodologies on specific aspects of the WRMP are referenced in the relevant sections throughout this document and are included in the Reference list.

The WRMP has to be maintained up to date and is therefore a live document that Bristol Water keeps under review. We are required to send the Secretary of State a statement of conclusions following each annual review of the published WRMP. The WRMP annual review process is a review of the current understanding of the components of the supply demand balance, based on the annual outturn data, and an assessment of how this compares to the final published WRMP. Any material change to the WRMP identified as a result of the annual review could trigger the need for the development of, and consultation on, a revised/updated WRMP.

2.3 Compliance with Government Direction

Our WRMP must comply with the *Water Resources Management Plan (England) Direction 2017,* which came into force on 22nd April 2017 and directs all water undertakers wholly or mainly in England as to the contents of our WRMPs. **Table 2-2** lists the requirements set out in the Direction, and where we have addressed these within this WRMP.

Table 2-2: Requirements of the Water Resource Management Plan (England) Direction 2017 have been addressed in the WRMP

Direction 2017 Reference	Contents of WRMP required by the WRMP (England) Direction 2017	WRMP Reference
2 (1)	A water undertaker must prepare a water resources management plan for a period of at least 25 years commencing on 1st April 2020;	16
3 (a)	The appraisal methodologies which it (the water undertaker) used in choosing the measures which it has defined in accordance with section 37A(3)(b) and its reasons for choosing those measures;	Each section lists relevant methodologies
3 (b)	For the first 25 years of the planning period, its estimate of the average annual risk, expressed as a percentage, that it may need to impose prohibitions or restrictions on its customers in relation to the use of water under each of the following: (i) section 76 (ii) section 74(2)(b) of the Water Resources Act 1991 (b); and (iii) section 75 of the Water Resources Act 1991, and how it expects the annual risk that it may need to impose prohibitions or restrictions on its customers under each of those provisions to change over the course of the planning period as a result of the measures which it has identified in accordance with section 37A(3)(b);	16
3 (c)	The assumptions it has made to determine the estimates of risks under sub-paragraph (b), including but not limited to drought severity;	6, 7, 10, 11, 17
3 (d)	The emissions of greenhouse gases which are likely to arise as a result of each measure which it has identified in accordance with section 37A(3)(b), unless that information has been reported and published elsewhere and the water resource management plan states where that information is available;	14
3 (e)	The assumptions it has made as part of the supply and demand forecasts contained in the water resources management plan in respect of –	7

Direction 2017 Reference	Contents of WRMP required by the WRMP (England) Direction 2017	WRMP Reference
	(i) the implication of climate change, including in relation to the impact on supply and demand of each measure which it has identified in accordance with section 37A(3)(b);	16.4.4
	(ii) household demand in its area, including in relation to population and housing numbers, except where it does not supply, and will continue not to supply, water to domestic premises; and	7
	(iii) non-household demand in its area, except where it does not supply, and will continue not to supply, water to non-domestic premises or to an acquiring licensee;	7
3 (f)	Its intended programme for the implementing of domestic metering and its estimate of cost of that programme, including the costs of installation and operation of meters;	8.1
3 (g)	Its estimate of the number of premises which will become subject to domestic metering during the planning period as a result of – (i) optant metering; (ii) change of occupancy metering; (iii) new build metering; (iv) compulsory metering; or (v) selective metering, and its estimate of the impact on demand for water in its area of any increase in the number of premises subject to domestic metering;	7, 8 and WRMP Tables
3 (h)	Its assessment of the cost-effectiveness of domestic metering as a mechanism for reducing demand for water by comparison with other measures which it might take to meet its obligations under Part III of the Act;	13, 16 and comment below
3 (i)	Its intended programme to manage and reduce leakage, including anticipated leakage levels and how those levels have been determined; and	8.2
3 (j)	If leakage levels are expected to increase at any time during the planning period, why any increase is expected.	N/A

In order to comply with Direction 3(h) we are required to set out the costs and associated reductions in demand relating to the following metering types: Selective, Change of occupancy, and Optant. As set out in section 8.1 our baseline metering policy includes metering on change of occupancy as well as an optant programme. We also considered further options for additional metering under selective programmes and further optants (section 13.4). In order to meet the requirements of the Direction we have collated the cost effectiveness information for all these types of metering in the table below

Option	Benefit (Ml/d)	AIC (£/Ml)
Selective metering of domestic customers based on (a) high consumption e.g. sprinkler use and/or (b) zones of high demand	0.57	95.74
Change of occupancy metering	0.57	95.74
Meter Optant	0.572	95.41

Our assumption is that the cost and benefit of metering on change of occupancy is the same as selective metering because it is essentially a selective policy i.e. the customer has not chosen to be metered, so their behaviour in terms of demand saving assumptions will be similar to other customers metered using other selective methods. The costs associated with the installation of meters for all types of metering are the same, apart from new properties, so it is just the assumed demand saving that varies the overall cost-effectiveness of the metering options.

2.4 Water Resource Plan Structure

This WRMP technical report takes the reader through the process we have implemented to develop our WRMP. We start with a general introduction to the company's supply area, and then set out each of the technical assessment areas used to determine the forecasts of supply (water available for potable use) and demand (the forecasted demand from customers) over the planning period. These assessments are then combined to derive the baseline supply demand balance that identifies whether there may be a risk of a supply deficit in the future. Any future deficit is addressed via the appraisal of options available to reduce or eliminate the deficit. The preferred plan is then set out showing how we propose to maintain customer security of supply and levels of service over the 25-year planning period.

This WRMP is therefore structured as follows:

- *Section 1: Executive Summary*
- *Section 2: Introduction*
- *Section 3: Engagement with Customers*
- *Section 4: Background Information*
- *Section 5: Problem Characterisation*
- *Section 6: Water Supply*
- *Section 7: Water Demand Forecast*
- *Section 8: Baseline Metering, Leakage and Water Efficiency*
- *Section 9: Sustainable Abstraction*
- *Section 10: Climate Change*
- *Section 11: Target Headroom*
- *Section 12: Baseline Supply-Demand Balance*
- *Section 13: Options Appraisal*
- *Section 14: Environmental Appraisal*
- *Section 15: Programme Appraisal*
- *Section 16: Final Water Resources and Demand Strategy*
- *Section 17: Testing the WRMP*
- *Section 18: Future Developments*
- *Section 19: Security Statement*
- *Glossary of Terms*
- *References*

Appendices are presented separately from this report but include:

- *Appendix A: Atkins Assurance Report*
- *Appendix B: Pre-Consultation List*
- *Appendix C: Research methods and outputs relevant to the development of the WRMP*
- *Appendix D: Customer Insight by Attribute*
- *Appendix E: Strategic Environmental Assessment Environmental Report*

- *Appendix F: Habitats Regulation Assessment*
- *Appendix G: Problem Characterisation*
- *Appendix H: Options Appraisal Options*
- *Appendix I: Water Framework Directive Assessment*
- *Appendix J: Ecosystem Services Assessment*

A number of supporting documents informed the development of this plan which are available by request.

2.5 Internal review and audit

In the development of our WRMP we have implemented a rigorous process of internal challenge, review, assurance and audit. This has been overseen via our internal WRMP Working Group (technical level) and the WRMP Steering Group (strategic director level), both of which have met on a regular basis during the development of the WRMP in order to be updated on the latest project developments. At these meetings the key components for developing the WRMP have been reviewed and challenged. We also commissioned consultants Atkins to provide external technical assurance to the company in terms of the methodologies and approaches used to develop the draft WRMP and the final WRMP and the data used to support the Plan. For each aspect of the plan, the following was reviewed during internal and external audits:

- Compliance with the reporting requirements and general compliance with good practice as referred to in the EA Water Resources Planning Guidance (WRPG).
- Technical adequacy of the approach used and the modelling and analysis behind it.
- The quality assurance and input/output controls used by Bristol Water and, where appropriate, the consultants that were engaged to provide the relevant models and assessment work.

The Atkins external auditor's report on the WRMP is in **Appendix A**. Atkins concluded that except where specifically noted in their report, Bristol Water has collated its submission in accordance with the Water Resources Planning Guidelines and the associated UK Water Industry Research (UKWIR) guidance notes. Atkins have confirmed that the technical approaches used generally comply with standard water industry practice to a level that is appropriate for the relatively low level of investment proposed within the WRMP19.

Each area reviewed at audit was allocated an overall rating of Red, Amber or Green to reflect their priority, with separate ratings for the methodology and the data (see tables below). Descriptions for each category are given in the table below [**Table 2-3**].

Table 2-3: Assurance rating reflecting priority

Category	Description
RED	High Priority: Failure to comply with reporting requirements, major failure of methodology or data errors that may lead to rejection of the WRMP or could fundamentally alter the nature of the Plan once they are addressed.
AMBER	Medium Priority: Shortfalls in methodology and/or data that could attract regulatory attention and are outside the norms of standard industry practice, but are unlikely to fundamentally alter the nature of the WRMP.
GREEN	Low Priority: Activity is in line with standard practice and any issues are unlikely to affect the results of that particular aspect of the Plan.

Table 2-4a summarises the findings of the Atkins assurance for the draft WRMP19. We addressed those issues identified by Atkins as "amber" in its assurance report for the draft WRMP19, which centred on our leakage cost-benefit data, the assessment of drought resilience and our programme optimisation modelling approach. These areas for improvement or clarification were considered by Atkins as "unlikely to materially affect the draft plan". The technical assurance of the WRMP19 undertaken by Atkins concluded that updates made since the draft WRMP19 resulted in all areas of the WRMP19 being rated as "not judged to be material or no issues" (see **Table 2-4b**).

Table 2-4b summarises the findings of the Atkins assurance of the WRMP for each key component reviewed, confirming that the activities and processes underpinning the plan are in line with standard practice and any issues are unlikely to affect the results of that particular aspect of the Plan.

As detailed in **Section 1**, this WRMP has been approved and signed off by Bristol Water's Board and by the Executive Directors.

Table 2-4a: Draft WRMP Assurance Outcomes

Technical component	Methodology	Data	Key Notes and Rationale	Agreed Actions
Target headroom	GREEN	GREEN	Some changes made to inputs following audit, but no material issues	None required
Outage	GREEN	GREEN	Some uncertainty, but in line with good practice	None required
Climate change	GREEN	GREEN	Good practice used on the surface water side. Groundwater not covered, but the risk is not material to the Plan.	None required
Demand forecast	GREEN	GREEN	Good practice and good QA.	None required
Decision-making model	AMBER	GREEN	The model concept is appropriate, but we noted some key methodological issues that were still being worked upon and will need to be addressed for the final plan. However, these are not material to the Plan unless the supply/demand balance changes significantly.	Between the draft and final plan the method will be finalised and confirmed and will be subject to further assurance. Any changes will be detailed within our Statement of Response.
SELL assessment	GREEN	AMBER	We have concerns over the outputs from the SELL model, as cost curves are unusually 'flat' and hence result in a very low incremental cost of leakage control. Leakage reduction has currently therefore been manually constrained to 6Ml/d in total or the draft WRMP, but this is likely to attract regulatory scrutiny and will need to be addressed for the final Plan.	Between the draft and final plan the method will finalise the SELL assessment which will provide greater certainty regarding the costs of leakage control. Any changes will be detailed within our Statement of Response.
Options development and	GREEN	GREEN	Approach is consistent with standard practice	None required

Technical component	Methodology	Data	Key Notes and Rationale	Agreed Actions
appraisal				
Options costing	GREEN	GREEN	Although cost uncertainty is quite high, that is normal for outline designs at the daft stage, particularly where proposed supply side investment is very low.	None required
WRMP modelling and resilience analysis	AMBER	AMBER	Currently there are relatively large uncertainties about the relative risk posed by both the worst historic drought event, largely due to the groundwater side, and from droughts outside of the historic record. These were addressed through the use of suitable Target Headroom allowances and re-assessment of analytical curves, so material risks to the Plan are unlikely, but further work is required prior to the final plan.	Between the draft and final plan we will be undertaking further work to increase the certainty of the drought assessment (see Section 6.2). Any changes will be detailed within our Statement of Response. For future WRMP we will be undertaking an updated deployable output assessment of groundwater sources.
WRMP tables	GREEN	AMBER	The tables have been completed according to reporting requirements, but we note that the very low incremental costs that have been entered for leakage control are likely to attract regulatory attention. These are not material in the overall context of the Business Plan totex, but are likely to be regarded as significant by the EA.	WRMP tables will be updated with updated leakage costs following the final SELL assessment.
SEA / HRA	GREEN	GREEN	Assessment in line with standard practice.	None required
WFD	GREEN	GREEN	Assessment in line with standard practice.	None required

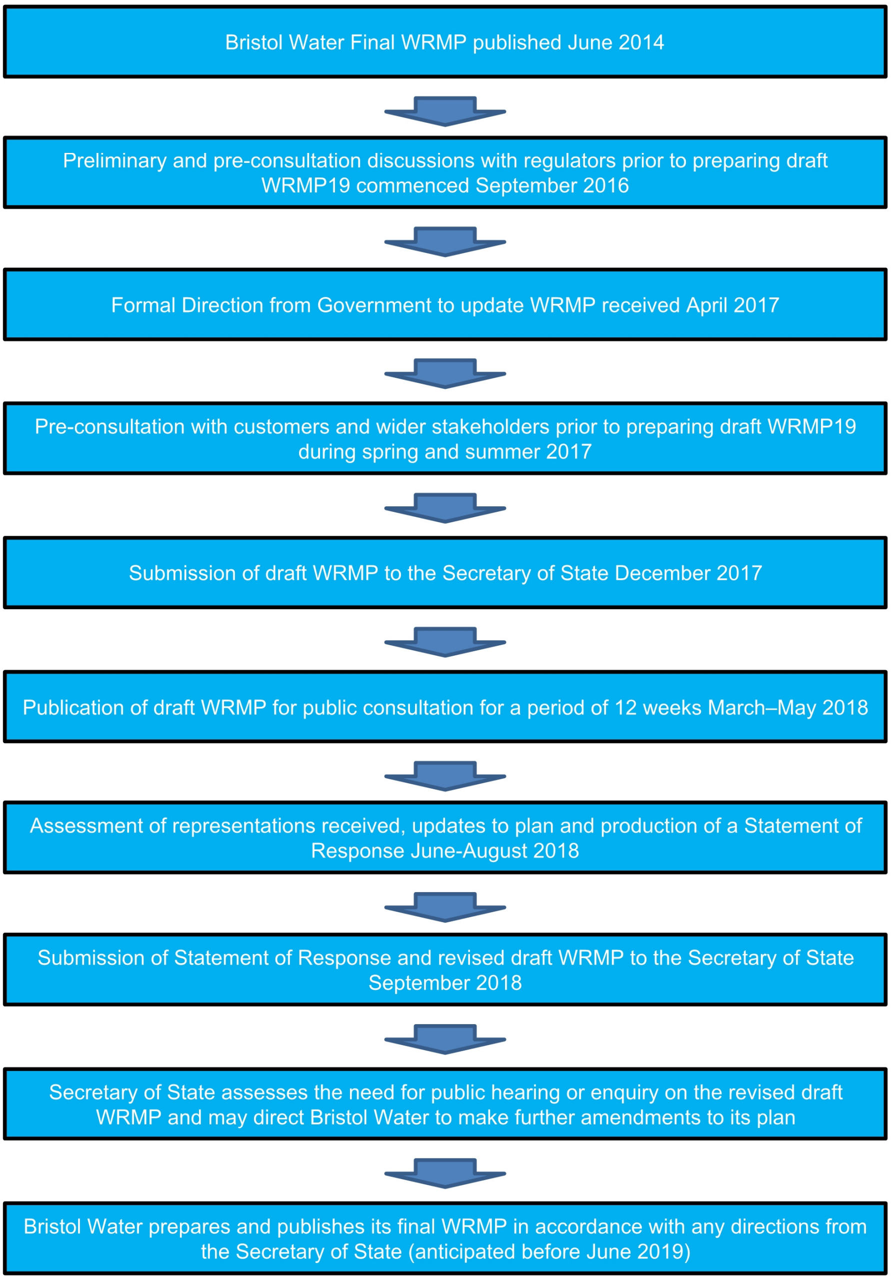
Table 2-5b: WRMP Assurance Outcomes

Technical component	Methodology	Data	Assurance summary
Demand forecast	GREEN	GREEN	We reviewed the approach taken for updating the demand forecast and did not identify any material issues.
Water resources modelling and resilience analysis	GREEN	GREEN	Following the identification of several 'amber' issues for the draft WRMP, we observed that the approach used for the revised WRMP was reasonable and we had no significant concerns over the 1 in 200 year DO.
SELL assessment	GREEN	GREEN	Although we have concerns about the approach being used to model the ALC costs (as noted in our previous audits), the validation process suggests that the Company now has appropriate ownership of the estimates and has confidence in the overall expenditure required to achieve its target in AMP7.
WRMP tables	GREEN	GREEN	We followed the audit trails and confirmed the figures in the tables. We recommended an update to one of the figures in Table 10 that should help to avoid confusion.

2.6 Timeline and finalisation of the WRMP

The flow chart in **Figure 2-2** illustrates the regulatory process and timeline for the development of our WRMP19.

Figure 2-2: Regulatory process and timeline for developing WRMP19



3 Engagement with customers, stakeholders and regulators

Section Summary

We consider that our Water Resource Management Plan (WRMP) should be driven by our customers' preferences, whether this is on environmental protection; the level of resilience we should target in the long-term; measures to reduce demand; or customer bills. By engaging effectively with our customers, we have gained valuable insights into their preferences and have developed a Plan which meets current and future need for water management in the most resilient, sustainable and affordable way.

This section provides information on the consultations we have carried out with customers when developing our draft and revised draft Plan, as well as the structured consultation activities we have followed with our regulators and other key stakeholders. This engagement has involved several innovative approaches, such as our online customer panel, customer preference testing with games at festivals and full-day deliberative workshops. The engagement has enabled us to create a programme of water resource management activity that has allowed testing and refinement of our Plan with customers during its development as well as the development of our related PR19 business plan.

We consider that stakeholder and customer engagement should be a continuous process: the successful engagement that we have carried out for the development of this Plan is part of our ongoing programme of engagement to ensure that our water resource planning, overall business planning and long-term strategies are fully integrated with each other and fully reflective of our customers' preferences.

Our Customer Challenge Panel has played a key role in developing and challenging the engagement process we have followed with customers, regulators and stakeholders and the Board is grateful for the contribution made by the members of this independent expert panel in ensuring we follow a robust process of customer engagement in developing our Plan.

The recently formed West Country Water Resources Group provides a P01-02R where we can share best practice with other water companies, regulators and major water abstractors to understand the opportunities and shared issues on water management in the region.

3.1 Pre-consultation on the draft WRMP

Throughout the development of the draft WRMP we worked with our customers, stakeholders and regulators in order to identify and act on their views and feedback. Our pre-consultation process ensured that interested parties have had an opportunity to input and contribute to the development of the draft WRMP.

The main elements of this pre-consultation process are set out in **Table 3-1**. The programme included consultation with regulators, stakeholders, neighbouring water companies and customers. We worked closely with the Environment Agency and the Bristol Water Challenge Panel in developing our draft Plan explaining the framework, technical methodologies, assumptions and decision making processes to ensure all parties were suitably informed to allow directed challenge and debate.

Table 3-1: ***Bristol Water pre-consultation engagement activities to support draft WRMP development***

Group	Organisation/Activity	Details of engagement process
Customers	Bristol Water Challenge Panel	Independent group of interested and expert stakeholders who ensure that the customer voice remains at the heart of Bristol Water decision-making. The Panel meets quarterly
	Customer Research	Online customer panel ‘let us know’. Surveys every 3 months about Bristol Water and the things that matter to our customers. Programme of customer engagement workshops and various willingness to pay surveys. See **Section 3.1.1**.
Regulators	Environment Agency	Series of technical pre-consultation meetings held from February to August 2017. Quarterly Bristol Water Tri-partite Group meetings, to discuss all environmental and water resource work areas
	Natural England	Quarterly Bristol Water Tri-partite Environmental Group meetings, to discuss all environmental and water resource work areas. Invitation to relevant technical pre-consultation meetings
	Ofwat	Pre-consultation meeting held on 14th July 2017
Water Suppliers	Water companies	Ongoing discussions with a number of water companies. Details provided in **Section 3.1.4**. West Country Water Resources group convened in June 2017 (Bristol Water/Wessex Water/South West Water (including Bournemouth) Southern Water/EA)

In May 2017 we carried out a formal pre-consultation process, writing to over 100 organisations and individuals, setting out the process we were implementing to update the WRMP and asking for any recommendations or considerations to be submitted to us in writing so we could take them into account during our review process. A list of the organisations contacted is provided in **Appendix B**. We received four formal responses to this consultation process from the Environment Agency, Bristol Water Challenge Panel, North Somerset Levels Internal Drainage Board and British Nuclear Group, although the response from the British Nuclear Group was acknowledging that they had no comments. **Table 3-2** summarises the comments received and where we have addressed them in the Plan.

Table 3-2: Comments from organisations responding to our formal pre-consultation process

Organisation	Summary of comments	Comments addressed in section
Environment Agency	• *Assessing resilience of the supply system to a range of droughts, including an assessment of the 1 in 200 year drought event scenario*	4, 6, 10, 11, 13, 14, 15, 17
	• *Assessing the likely effects of climate change*	1, 2, 3, 6, 7, 10, 11, 14, 15, 17, 18
	• *Consideration of water trading options with neighbouring water companies and wider third party involvement*	13
	• *Meeting the requirements of the Water Framework Directive (WFD) and the water industry national environment programme*	2, 13, 14
	• *Following a 'twin track' approach to supply demand management*	8, 13, 16
	• *The WRMP should reflect all relevant guidance including Defra Guiding Principles and the Water Resource Planning Guidelines*	Throughout plan
	• *Consideration should be given to the outputs of the Water UK project 'Water Resources Long Term Planning Framework' and what this means for Bristol Water*	6, 10
	• *The WRMP should include a reducing target*	

Organisation	Summary of comments	Comments addressed in section
	headroom profile to reflect that uncertainty will reduce as you move through the planning horizon • *Reviewing the calibration of the rainfall runoff model in light of recent work at P39R, P42R and P10R* • *Updating the demand forecast with the latest planned housing development and population projections. The plan should demonstrate how per capita consumption is reducing as required under Defra's Guiding Principles* • *Environmental attributes relating to Bristol Water's activities should be fairly represented within the WRMP against non-environmental parameters* • *Test resilience options with customers to explore willingness to pay for different levels of service (increased resilience to drought) in the future*	11 6, 10 7 Throughout plan 3, 4
Bristol Water Challenge Panel	• *Continued direct engagement with the BW Challenge Panel on the planning activities, explaining assumptions and results along the way* • *Consider resilience both in terms of water resources and the ability of the environment to withstand changes in water supply and customer demand* • *Customers have a responsibility for water resources and environmental resilience as well as Bristol Water. Resilience should be presented in the context of finite resources, vulnerable supply networks and a fragile environment* • *Provide a companion customer summary document to the technical dWRMP, including cross referencing within the summary document to the dWRMP and setting out links to the Business Plan*	3 1, 2, 3, 4, 6, 8, 13, 15, 16, 17 8.3, 9 Non-Technical Summary

Organisation	Summary of comments	Comments addressed in section
	• *Use innovative ways to engage with customers as part of the dWRMP public consultation process*	3
North Somerset Levels IDB	• *Give consideration to the wider impact of Bristol Water abstraction in the Board's District in the production of the WRMP*	9
	• *Recognise that the watercourses managed by the IDB (known as rhynes) are considered waterbodies under the Water Framework Directive*	9

3.1.1 Customers – Customer Research

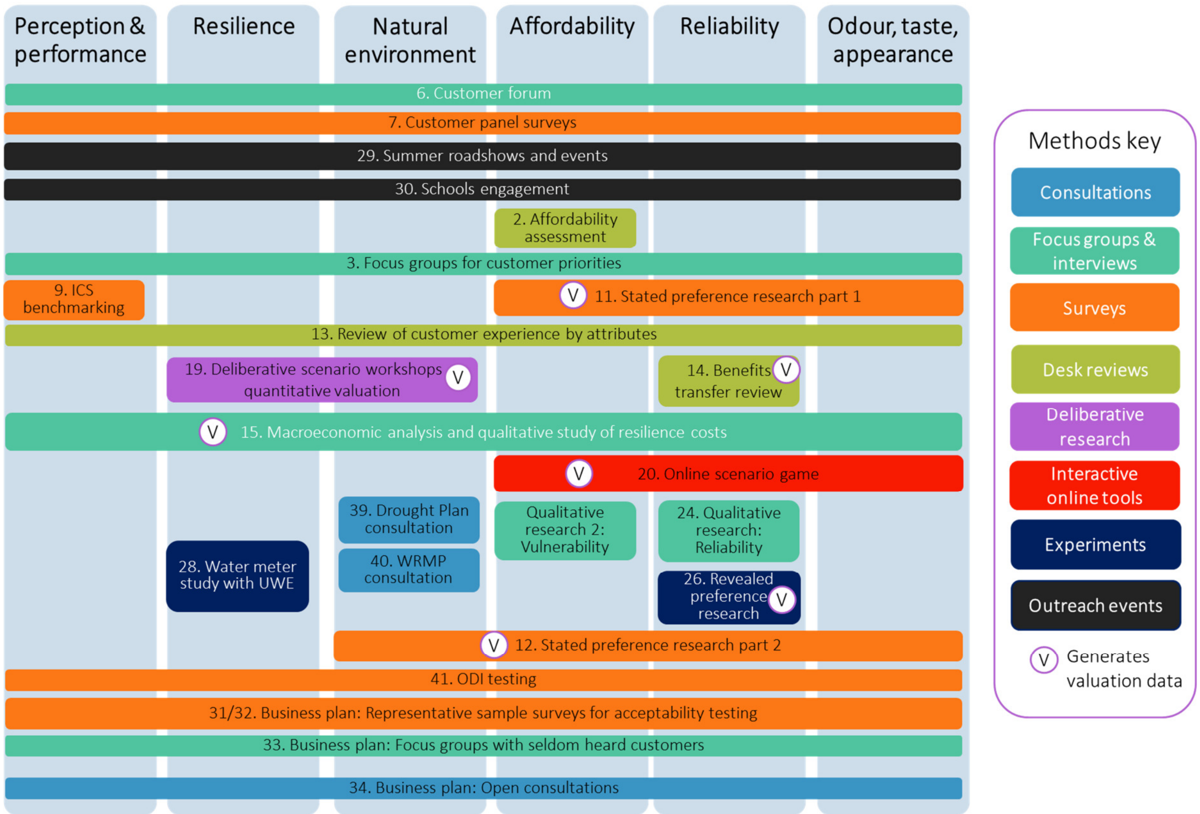
As part of the PR19 business planning process, and to support the development of our WRMP, we developed a customer engagement framework (**Figure 3-1**). This engagement framework laid out a schedule for mixed-methods research and engagement to enable us to understand customer views and to bring the voice of the customer into the centre of our decision-making processes.

The customer engagement framework included valuation research, quantitative customer surveys, qualitative customer research (such as focus groups, interviews, and deliberative engagement events), ongoing customer insight data (such as that captured from inbound customer contacts, complaint data, and satisfaction cards) and acceptability research and testing. Some of the customer engagement was designed to inform particular decisions – for example deliberative events on resilience and a stated preference specifically focused on water resource management options, whilst others have been designed as ongoing initiatives as means of integrating the customer voice throughout business activities.

In its Water 2020 consultation, Ofwat stated that it expects to "see companies developing a robust, balanced and proportionate evidence base and [it] accept[s] that a one-size-fits-all approach will not work for customer engagement". At PR14 many companies relied substantially on Stated Preference or Willingness to Pay research carried out rigidly as defined in 2011 UKWIR guidance. Ofwat has stated that "[while] stated preference willingness to pay (WTP) approaches will continue to have an important role to play at PR19, it is also important for companies not to place sole or disproportionate reliance on such methods". Ofwat has encouraged companies to "triangulate" results from stated preference surveys with a wider range of valuation evidence obtained through day-to-day contact with customers, innovative techniques such as Revealed Preference research, and by applying behavioural economics insights to the design and interpretation of customer engagement, including possible enhancement to stated preference methods. The basic principle is to use several different methods to estimate the same value, and critically assess the different results to get a more robust picture.

The views and priorities of our customers are core to developing both our WRMP and our Business Plan. This approach has informed our company levels of service (in terms of the frequency of restrictions on water use) and preferences for the options we should implement in order to manage customer demand and provide additional water supply if necessary. The outcomes of the customer research have been referenced throughout this document within the relevant section of the plan.

Figure 3-1: Bristol Water's Customer Engagement Framework



The customer research data are a combination of valuation data (which has provided a monetary value against key service levels defined as households (hh) and non-household (nhh) customer) and other relevant data (both quantitative surveys and qualitative research demonstrating customer views and priorities). In line with Ofwat expectations, most of the valuation data has been 'triangulated' to provide greater certainty in the data. Customer research is referenced throughout this WRMP, and the full list of the research and overall results are presented in:

- **Appendix C**- Research methodologies and outputs relevant to the development of the WRMP: Document provides an overview to the methods and key outcomes of the research.

- **Appendix D**- Customer Insight by Attribute: Provides an overview of all customer research where the outcomes are presented by attribute i.e. leakage and metering and not by research programme.

Further customer engagement

The research and engagement undertaken for the draft Plan significantly improved our understanding of our customers' views and preferences, as reflected in our draft WRMP. However, the customer research process continued as part of our public consultation on the draft plan as described in our Statement of Response published on our website and which informed the development of this revised draft WRMP19 and subsequently this final Plan. In addition to general customer engagement via road shows and the Online Panel, Bristol Water hosted three deliberative engagement sessions with customers in February and March 2018 to explore their views, with a particular emphasis on demand reduction options (including metering and water efficiency) as well as seeking views on the proposals set out in our draft WRMP. The outputs of this research are summarised below.

Participants generally supported the proposals in the draft WRMP, although they were concerned about (an incorrectly perceived) increase in bills as a result of implementing the Plan. They valued a balanced approach to risk in the short- and long-term, and felt confident that Bristol Water would ensure an adequate water supply in the future. Participants' primary motivations in decision-making were effectiveness and cost.

Although participants felt that Bristol Water should be responsible for the costs and measures required to combat the forecast supply-demand deficit, they supported an approach that would share the burden with customers. They appreciated that customers are responsible for part of the future demand growth, and that changing behaviour of current and future customers could make a significant difference in the long-term. In this regard, participants emphasised issues they believed should be the focus of education and awareness raising programmes:

- available water efficiency devices, how they work, the benefits, and how to access them;
- the benefits of water metering, why metering is needed, and the link between leakage and metering;
- Bristol Water's supply network, water sources, and challenges; and
- the forecast supply deficit, what Bristol Water is doing about it, and what customers can do.

Demand management was significantly more favoured than increasing supply to resolve the forecast deficit. However, participants believed that in the long term, supply would need to be increased to keep up with population growth. Active leak control (ALC), water metering, and pressure management were the preferred demand management approaches, although there was some strong opposition expressed in respect of pressure management and water metering. Participants' views were generally not influenced by whether or not they had a water meter, even for metering.

Participants' views supported the findings of Bristol Water's previous customer engagement:

- they showed a preference for demand reduction over increased supply;
- they regarded leakage reduction as a high priority;
- they regarded water efficiency as important;
- they were willing to pay to avoid a supply-demand deficit;
- they supported metering, but were concerned about affordability and fairness; and
- they valued protecting the environment.

The outputs from this research since we published the draft Plan have been used in the development of our revised draft WRMP and this final WRMP.

3.1.2 Customers – Bristol Water Challenge Panel

The predecessor group to the Bristol Water Challenge Panel, known as the Local Engagement P01-02R, was first established in 2012 to support development of the WRMP14 and the Periodic Review 2014 (PR14) Business Planning process. In 2016 the group was re-named and refreshed as the Bristol Water Challenge Panel in order to support the PR19 process and the WRMP19. The Bristol Water Challenge Panel is an independent group of interested and expert stakeholders whose role is to ensure that customer voice remains at the heart of Bristol Water's decision making. One of the key roles of the Challenge Panel is to help us develop Business Plan proposals that reflect the views of customers as well as the interests of other stakeholders and the environment. This includes the development of the WRMP and how this informs the business planning process.

Peaches Golding OBE is the independent Chair of the Challenge Panel, and the following organisations are currently members of the Panel:

- *Avon Wildlife Trust*
- *Bath University*
- *Bristol City Council*
- *Consumer Council for Water*
- *Citizens Advice Bristol*
- *Environment Agency*
- *Natural England*
- *North Somerset Council*
- *University of the West of England*

The Panel meets quarterly and the minutes of the meetings are available on our web site: https://www.bristolwater.co.uk/about-us/learning-from-you/challenge-panel/

Throughout the development of the WRMP we have provided regular progress updates to the Challenge Panel at their quarterly meetings. This direct engagement focused on explaining the assumptions and results of each of the components of the WRMP as the work progressed, so the Panel members had a clear understanding of the overall process, and opportunity to comment on and influence that process as it develops.

3.1.3 Government and regulators

Environment Agency:

We implemented a programme of technical pre-consultation on the draft WRMP19 with the Environment Agency in September 2016. An outline of the meetings held and the technical areas covered at each meeting is set out in **Table 3-3.** The purpose of the technical pre-consultation discussions was to outline the methods and approaches we have implemented in developing the draft WRMP19 in order to reduce the need for changes later in the process and ensure that close liaison between Bristol Water and Environment Agency was maintained. As part of this pre-consultation process we also issued method statements to the Environment Agency for discussion and comment, describing the methods we used in developing specific technical areas of the WRMP.

Table 3-3: Programme of Environment Agency WRMP19 technical pre-consultation meetings

Technical area covered	Date(s) of meeting(s)
Pre-consultation start-up meeting	19th Sept 2016
Demand forecast	12th Dec 2016 and 28th Feb 2017
Problem characterisation	28th Feb 2017
Climate change modelling	28th Feb 2017
Deployable output assessment	28th Feb 2017 and 17th Jul 2017
Headroom assessment	1st Mar 2017
Outage assessment	1st Mar 2017
Options appraisal	9th Mar 2017
Economics of Balancing Supply & Demand (EBSD) assessment	9th Mar 2017
SEA/HRA methodology scope and approach[1]	27th Apr 2017
Pre-consultation overview meeting	23rd Aug 2017
Pre-consultation overview meeting	30th October 2017

[1]Natural England and Natural Resources Wales also attended meeting. Welsh Government, Cadw and Historic England also invited to take part in this element of the consultation process.

In addition to the technical pre-consultation process, we also set up a 'Tri-partite Environmental Group' whose purpose was to provide strategic oversight of the environmental issues (regulatory and other) affecting the development of our PR19 Business Plan and the WRMP19. The Group also provided a P01-02R where any issues and gaps identified, but not resolved through the technical meetings could be escalated for resolution.

The primary stakeholders in the Group were Bristol Water, Environment Agency and Natural England, although there was also representation from the Bristol Water Challenge Panel to enable clear communication of customer issues between the Tri-partite Group and the Challenge Panel. The Tri-partite Group was initiated in December 2016 and has since been meeting on a quarterly basis.

As part of the preparation for our Strategic Environmental Assessment (SEA) and Habitats Regulation Assessment (HRA) the Environment Agency was consulted on the scope and approach of the SEA and HRA methodologies. Further details of this process are set out in the SEA Environmental Report and HRA report accompanying our Plan at **Appendices E** and **F**, respectively.

Natural England:

Natural England has been represented on our 'Tri-partite Environmental Group' as outlined above. Natural England has also been invited to some of the Environment Agency technical pre-consultation meetings for areas they are interested in, for example deployable output assessment.

As a statutory consultee, Natural England was consulted on the scope and approach for the SEA and HRA methodologies. Further details of this process are set out in **Appendix E** and **F**.

Historic England:

As a statutory consultee, Historic England was consulted on the scope and approach we have used for the SEA and HRA methodologies. Further details of this process are set out in **Appendix E** and **F**.

Natural Resources Wales & Welsh Government:

In response to our supply-side options list which considered the possibility of transfers from Wales, we included Natural Resources Wales (NRW) and representatives of the Welsh Government in our consultation on the scope and approach used for the SEA and HRA methodologies. Further details of this process are set out in **Appendix E** and **F**.

Ofwat:

In December 2016, Ofwat wrote to all water companies setting out their expectation and approach to their pre-consultation engagement for WRMP19. In response to this we held a pre-consultation meeting with Ofwat on 14th July 2017, during which we covered the methodologies and approach we were implementing for the dWRMP19. This meeting took the place of a written response to our formal pre-consultation process implemented in May 2017. Subsequent to this meeting Ofwat issued an additional request for further information, which we fulfilled on 11thAugust 2017.

3.1.4 Stakeholders

Water companies:

We have carried out formal pre-consultation discussions with all our neighbouring water companies and organisations who may have an interest in the water resources that we use, such as the River Severn, as well as exploring options for water trading (both changes to existing water trading arrangements and opportunities for new water trading). A list of the companies we consulted during the pre-consultation phase of developing our plan and the dates of the meetings is presented in **Table 3-4**. This consultation process has been ongoing since these meetings, continuing to engage with water companies as required throughout the development of our WRMP19 and following completion of our consultation on our draft plan. In particular, we have continued dialogue through the newly formed West Country Water Resources Group (see below) as well as specific consultation with Wessex Water on our bulk export agreement as part of developing our final WRMP.

Table 3-4: Pre-consultation with other water companies

Water Company	Date(s) of meeting(s)
Thames Water	16th Aug 2016
United Utilities	21st Nov 2016
Dwr Cymru Welsh Water	2nd Dec 2016 & 25th May 2017
Severn Trent Water	15th Dec 2016 & 2nd Jun 2017
Wessex Water	6th March 2017 & 4th Aug 2017

West Country Water Resources:

The West Country Water Resources group was formed in June 2017 to support a co-ordinated approach to water resources planning in the south west of England and neighbouring water company areas. Initially the group has focused on supporting the development of the WRMP19s, including exploring the opportunities for water trading, with the longer-term aim of working towards collaboration for the WRMP24 submissions and development of an integrated regional water resource plan. Membership of the group is open to all water companies, regulators and others by invitation who have WRMP related interests in the abstraction and use of water in or from the South West. The group currently consists of Bristol Water, Wessex Water, South West Water (including Bournemouth Water), Southern Water and the Environment Agency. Minutes of meetings are recorded and distributed with relevant parties.

River Severn Working Group:

The River Severn Working Group was formed in May 2017 and was set up to coordinate assessment and evaluation of strategic planning matters related to the use of water from the River Severn, with a particular focus on resource development options under consideration for WRMP19 and the development of a list of options available for future raw or treated water transfers/trades. Membership of the group is open to abstractors and regulators with water resources related interest in the use of water in the Severn catchment. Current representation on the group includes: Natural Resources Wales (NRW), Environment Agency, Natural England, United Utilities, Severn Trent Water, South Staffs Water, Bristol Water, Thames Water, Dwr Cymru Welsh Water, Energy UK, Agriculture NFU, Canal & River Trust, Defra (via EA). Minutes of meetings are recorded and distributed to relevant parties.

3.2 Compliance with guidelines on consultation

As set out in **Section 3.1**, we implemented an extensive programme of pre-consultation on our draft WRMP19. This met and exceeded the requirements for pre-consultation as set out in Section 37A(8) of the Water Industry Act 1991 and the Environment Agency *Water Resources Planning Guideline: Interim updat*e (April 2017). The process we implemented for the formal public consultation on our draft WRMP19 is set out in **Section 3.3**.

3.3 Consultation process

The statutory process set out in the Water Industry Act 1991 requires us to publish our draft WRMP for public consultation. We published our draft WRMP19 (along with its Appendices which included a draft Strategic Environmental Assessment, a draft Habitats Regulations Assessment, a Water Framework Directive assessment and a Non-Technical Summary) for a twelve week public consultation period that ran from 8th March until 31st May 2018. This process provided customers and stakeholders with an opportunity to consider the proposals we set out in our draft WRMP in terms of managing the water resources and demand in our supply area, how this may affect them, and to provide us with any feedback and comments. Bristol Water values all feedback and we took the time to review all the comments received, and prepared a formal Statement of Response setting out how we have considered the comments received and taken them into account in developing our revised draft WRMP. Our Statement of Response was published and made available on our website on 5th September 2018 (within 26 weeks of publishing our dWRMP for consultation).

In February 2019, we received a request from Defra for some additional information to support the Statement of Response. We therefore updated our Statement of Response to address this request for information and reflected this on our revised draft WRMP19. The updated Statement of Response was published on our web site on 8th March 2019.

On 23rd July we received a letter from Defra confirming that we should publish our final Plan in accordance with regulation 6 of the Water Resources Management Plan Regulations 2007. This plan was published on 22nd August 2019, and is available on our web site:

https://www.bristolwater.co.uk/about-us/water-resources/

4 Background information

Section Summary

We have formally integrated our WRMP19 development, under Board direction, with our other planning processes including PR19, our Drought Plan and our operational plans. This section provides basic information about how and where we operate and how the water resource management planning process is one of the main drivers of our business planning and operations.

Our supply area covers c2400km^2, extending along the eastern flank of the Bristol Channel between Tetbury in the north and Glastonbury in the south. We currently supply approximately 1.19m people, from our Mendip Hills reservoirs and from groundwater within our supply zone, with nearly half our supply from a large abstraction from the R01 transferring water from outside our supply zone. Our system for managing water is highly interconnected and for the purposes of water resources planning we operate one integrated Water Resource Zone (WRZ) as agreed with our regulator.

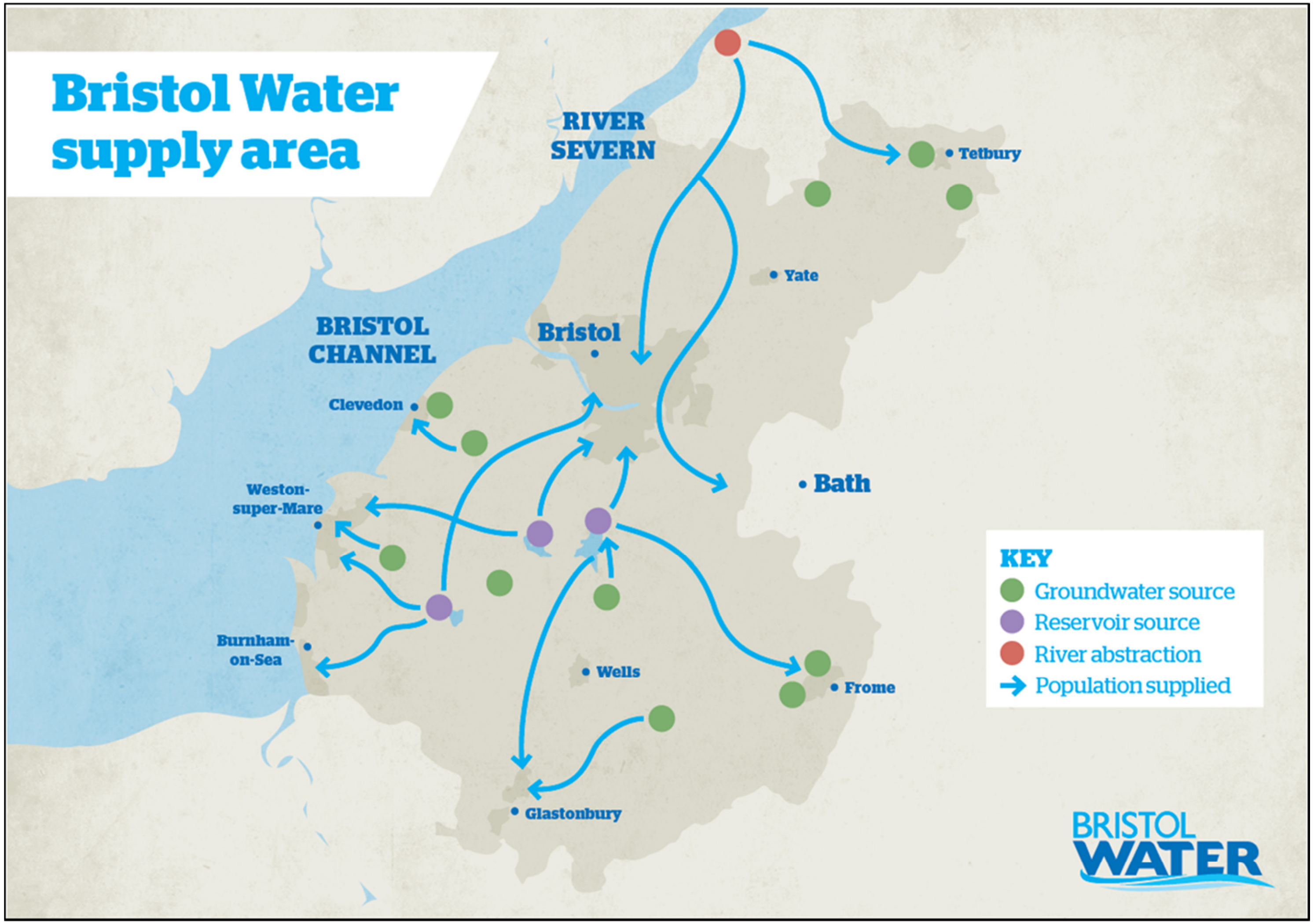
For WRMP19 we have carefully followed all relevant and up to date guidance issued by regulators, Government and the water industry, and have tested our plan against formal requirements such as the Strategic Environmental Assessment and Habitats Regulation Assessment requirements. Based on customer feedback during our extensive customer engagement programme, we will maintain our current levels of service for planned restrictions to supply.

4.1 Supply Area and Water Resources Zone

Bristol Water is a water-only company (WoC) that provides water supply in an area of approximately 2,400 square kilometres (1,000 square miles) with a population of approximately 1.19 million people. Our supply area ranges from Thornbury and Tetbury in the north to Street and Glastonbury in the south and from Weston-Super-Mare in the west to Frome in the east.

Water resource planning is undertaken at water resource zone (WRZ) level. A WRZ is defined as the largest area in which all water resources (including external transfers) can be shared and hence the zone in which all customers experience the same risk of supply failure from a resource shortfall and the same level of service for demand restrictions. Due to the integrated nature of our sources, we plan on the basis of operating the company area as a single WRZ as agreed with the Environment Agency. This means that all water resources within the company area are capable of being shared within the zone. Bristol Water uses the same WRZ for operational management, Drought Planning and water resource planning. Our supply area and the key features of our WRZ are illustrated in the map in **Figure 4-1**.

Figure 4-1: Bristol Water, water resource zone and associated infrastructure



4.2 Sources of supply

Only around half of the water supplied within the Bristol Water supply area is sourced from within it, with the rest being transferred into the zone from outside the area. This water is sourced from the R01 to supply our largest northern treatment works and accounts for approximately 46% of our licensed resource. The R01 is owned and operated by Canal & River Trust and is supplied by the River Severn and other local rivers, the Cam and the Frome. In periods of dry weather, use of this source is maximised in order to conserve the water stored in our reservoirs.

The intrinsic water resources within the WRZ include our Mendip Reservoirs and associated surface water abstractions, which account for approximately 42% of our available licensed resource.

The remaining water sourced from within the water resource zone is derived from groundwater and accounts for approximately 12% of our available licensed resource. These sources are operated at their optimum output to meet the base-load demand for water.

4.3 Progress with implementing the 2014 Water Resources Management Plan

We report our progress with implementing our existing WRMP to the Secretary of State for Environment, Food and Rural Affairs via a formal WRMP Annual Review process. Our last Annual Review was recently submitted in June 2018 and reported our progress with the demand management options set out in our WRMP14 which included a number of leakage and metering projects.

Our WRMP14 also set out plans for the development of P10R 2 Reservoir. Construction work on this scheme will no longer proceed during the AMP6 period, and our analysis of customer demand indicates that we no longer need to develop this resources within the timeframe presented in WRMP14. This is one of the significant changes made to our WRMP in the development of 2019 WRMP (as set out in **Section 2.1.1**); however, as described in **Section 2.1**, each WRMP builds on the last one by updating and reviewing the assessments to reflect the latest information. Our review of the justification of need for additional water resources within our supply area has been a significant part of this update process and will continue to be in the future.

4.4 Planning Period and Base Year

The Environment Agency Water Resources Planning Guideline (July 2018) states that WRMPs should take a long term view, setting a planning period that is appropriate to the risks faced by the water company, but which covers at least the statutory minimum period of 25 years. Bristol Water's Problem Characterisation process (see **Section 5**) identified that the scale and complexity of our water supply planning problem is currently relatively low, therefore we have chosen to use the 25 year planning period to develop our WRMP19, running from 2020/21 to 2044/45. If our assessments had indicated the need for a significant investment in a water resource option towards the end of the planning period, we would then have considered extending the selected planning period used in order to assess the long term requirements of such an investment. However, no such investment need has been identified.

The base year is the starting point for the forecasts and projections of future supplies and demands over the planning period. For the purposes of this WRMP the base year used for the supply/demand data is 2017/18, as this is the most recent year for which we have out-turn data. This is in line with the requirements set out in the Water Resources Planning Guideline (July 2018).

4.5 Planning Scenarios

Planning scenarios are based on a design 'dry year' condition, which is defined as a period of low rainfall but with unconstrained demand (i.e. no customer restrictions on demand such as Temporary Use Bans (TUBs)), since this is the scenario when the supply demand balance would be under the greatest stress.

The Environment Agency's Water Resources Panning Guideline (July 2018) requires all water companies to base their WRMPs on the dry year annual average (DYAA)[1] scenario (for demand) and the design drought (for supply).

The dry year critical period planning scenario (DYCP)[2] corresponds to the period of peak water demand, which normally occurs during the summer months of June, July and August. The peak period of demand is usually defined in terms of the average day peak week (ADPW) demand. Operational experience shows that critical period scenarios such as those based on ADPW are not appropriate for the Bristol WRZ, as it is not significantly peak constrained from a water resources perspective. Peaks are managed to lower the impact due to the integrated nature of our supply network and the storage provided by our Mendip reservoirs.

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, P10R, 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 we lose our northern supply. We will continue to address resilience risks of the supply network in our future plans.

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[1] The annual average value of demand, deployable output or some other quantity over the course of a dry year
[2] The time in a dry year when demand is greatest, often taken to be the peak week. Commonly known as the Summer Peak Period

We have used the DYAA scenario as the basis of our demand forecast for this WRMP, supported by an assessment of the deployable output and Water Available For Use from the design drought scenario to determine supply availability (see **Section 6** for further details on this assessment). The approach was shared with the Environment Agency during pre-consultation discussions on our draft WRMP19.

4.6 Links to Other Plans

4.6.1 Bristol Water Business Plan

The Business Plan sets out how much we need to spend to maintain and improve our service over the five years from 1 April 2020 to 31 March 2025 (this period is also referred to as AMP7), and the impact this will have on customer bills. The Business Plan therefore includes the first five years of the strategy set out in the WRMP, as well as any planning or investigations that may be required for schemes occurring in the longer term. This WRMP therefore also informs Bristol Water's Business Plan for the 2019 Periodic Review of Price Limits (PR19).

As part of the development of the WRMP, we have also considered the need to maintain resilience within our water supply system. Therefore, any water resource or demand management options identified within the WRMP relating to managing the resilience of our water supply system, are also included within our PR19 Business Plan submission.

4.6.2 Bristol Water Drought Plan

Our Drought Plan is an operational plan identifying how we intend to manage a future drought, what trigger levels will be used to identify when action is required and what measures are available to support supplies at risk when customer levels of service may be compromised. The Drought Plan sets out how the effects of a drought and associated drought actions will be communicated to our customers, and also takes account of the need to undertake environmental monitoring at any sites which could potentially be affected by implementation of drought actions.

We updated our Drought Plan for submission to Defra in January 2017, and carried out an 8 week public consultation on the draft Drought Plan from 27th March to 21st May 2017. We subsequently published a Statement of Response to this consultation on 7th July 2017 and produced a Draft Final Drought Plan to support this. Following minor additional considerations requested by Defra in April 2018, we published the Final Drought Plan on 21st June 2018. .

Our WRMP is consistent with the assumptions and measures set out in our 2018 Drought Plan. The Environment Agency WRPG (July 2018) introduced a number of requirements for water companies to set out more clearly the links between their Drought Plans and their

WRMPs (Environment Agency (November 2016) *Drought Plan and WRMP links*). These are addressed in Section 6.1 *Deployable Output* and Section 6.2 *Drought risk assessment*. Water companies are also required to set out in Water Resource Planning (WRP) Table 10 the drought measures and drought resilience that contribute to the deployable output of the design drought event and any other drought scenarios assessed, and the effects of additional drought measures set out in the Drought Plan but not included in the baseline deployable output assumptions.

4.6.3 EA Drought Plans

The EA have two drought plans which are relevant to our supply area: the Wessex Drought Action Plan (EA. 2016) and River Severn Drought Order Environmental Report (EA. 2013). Where relevant the potential linkages to these plans have been considered, for example in assessing the dry weather yield of the R01.

4.6.4 River Basin Management Plans (RBMPs)

Where new options have been identified an SEA, HRA and WFD assessment have been undertaken to determine any potential effects on the environment which would have implications on relevant RBMPs. In addition, an Ecosystem Services Assessment was undertaken for each option to identify the potential impacts and benefits of each option within the catchment.

The River Severn and South West River Basin Management Plan (RBMP) are relevant to our area of supply. These plans identify environmental enhancements currently undertaken by Bristol Water, for example our commitments under the Water Industry National Environment Programme (WINEP) as discussed further in **Section 9**. We will continue to work with local stakeholders to identify and resolve environmental issues.

4.6.5 Flood Risk Management Plans

Our existing assets have been assessed using the EA Flood Outlines Map to confirm that existing flood resilience investment carried out in AMP5 continues to provide an appropriate level of flood resilience. We are represented on the Strategic Flood Boards of all the major Authorities within our Supply Area.

Where new options have been identified via the Options Appraisal process an assessment of the potential effects to flood risk have been identified via the SEA and Ecosystem Services Assessment (**Section 14**).

4.7 Company Policies including Levels of Service

4.7.1 Planned level of service

Expectations about the frequency with which restrictions on water use are implemented during dry years are known as 'levels of service', and set out the standard of service customers can expect to receive from their water company. We are required by our regulators to both specify and report our levels of service, or frequency at which customers can expect to experience restrictions on water use and what types of restrictions these would be.

During extended periods of dry weather, it may be necessary to encourage increased customer water efficiency and to restrict customer demand, to ensure that adequate water supplies are maintained. Initial demand management actions therefore include encouraging customer restraint on water use through media campaigns.

As dry weather continues into drought conditions and the risk to water supply increases, more formal water use restrictions may be required such as temporary use bans (TUBs). In extreme drought conditions, Drought Orders may be needed to further restrict water use for commercial purposes.

We do not plan for a level of service that would guarantee there would never be any customer demand restrictions because this would require significant investment in additional water resource assets infrequently used resulting in unacceptably high water bills for customers. The planned levels of service for Bristol Water customers remain the same as they were in the 2014 WRMP, except for *Emergency drought order – partial supply or rota cuts* (Level 4 restrictions) which have been updated to reflect our improved understanding of the resilience of our system to a 1-in-200 year drought. Details of this assessment are set out in Section 6.1 and 6.1, The updated planned levels of service are set out in **Table 4-1**. This is consistent with the planned levels of service reported in our Drought Plan (June 2018) with the exception of the *Emergency drought order – partial supply or rota cuts*, which demonstrate improved understanding of our system resilience and security of supply for our customers, and is therefore not material to the integrity of our drought plan.

Table 4-1: Bristol Water levels of service and frequency of restrictions

Drought Action	Level of service
Temporary use ban (TUBs)	1 in 15 years on average
Drought Order – Non-essential use ban	1 in 33 years on average
Emergency Drought Order - Partial supply or rota-cuts	1 in 200 years

As detailed in **Section 3** we have conducted extensive customer research in order ensure our plan meets customer's expectations, specifically looking at customer preferences with respect to supply restrictions (TUBs, non-essential use bans and Emergency Drought Order). A summary of the research is presented below:

Temporary use bans

TUBs relate to hosepipe bans which may be applied over a 5 month period during a period of drought. Customers have a low willingness to pay to avoided TUBs at £0.4 per household/year (range of £0.1 to £1.8) and £2.8 per non-household/year (low range of £0.2) for a 1% reduction in probability. This is confirmed from qualitative research where most participants did not prioritise reducing the impact of disruptive events, such as drought, and felt that the current level of risk was acceptable (from the deliberate resilience research). Feedback from the online customer panel indicates that only 44% of panel members said 'avoiding hosepipe bans' is very or quite important. This was the second lowest priority. This therefore indicates that we have no strong reason to consider that customers have a significant preference for a different level of service.

The results of the Macroeconomics Impact of Drought assessment indicates non-household customers value leakage reduction and water efficiency measures as a response to drought. The low instance of drought in our supply area means that many customers have not experienced drought. We are aware that this can affect how they prioritise drought measures, as customers believe it is unlikely to affect them. During the deliberative events on resilience, we took care to give customers detailed scenarios of drought and helped them understand the potential impacts on themselves, their community, and the wider economy. While TUBs were not specifically discussed, it was noticeable that customers were overwhelmingly in favour of demand reduction measures in general.

Drought Order – Non-essential use ban

There is no specific economic valuation customer research relating to non-essential use bans, which would only affect non-household customers. Evidence from the use of TUBs indicates that non-households have a low WTP to avoid hosepipe bans; whilst not directly comparable the results do indicate a low value. This is confirmed from the outcome of the macroeconomic impacts of drought study which indicates non-household customers would prefer to reduce leaks and invest in greater water efficiency as a response to drought. This therefore supports our current levels of service.

Emergency Drought Order - Partial supply or rota-cuts

The outcome of the customer research indicates that customers have a strong willingness to pay to avoid partial restrictions on supply and rota cuts. There is a central value of £47.10 per household/year (range of £9.90 and £84.40) and £525.70 per non-household/year (range of £72.70 and £525.70) for households and non households respectively to avoid one day of restrictions.

The qualitative data from customer engagement supports a low valuation, and this may result from the fact that many customers have never experienced a significant drought and therefore are unable to place a value on drought avoidance. During the Annual Survey, ‘having a clear plan of how to maintain water supply during a drought’ was ranked as one of the lowest priorities for customers in 2017. However, despite the fact PR19 stated preference valuations were low and the outcome of qualitative research our improved understanding of the severity of the droughts we have used to determine our system deployable output demonstrates that we can maintain supplies without emergency drought orders in at least a 1 in 200 year drought event. We have therefore updated our levels of service for *Emergency drought orders – partial supply or rota cuts* from 1 –in-100 years, to 1-in-200 years. Details of the assessment carried out to support this change are set out in Section 6.1 and 6.2.

This change in level of service results in an inconsistency between our WRMP19 and the level of service reported in our Drought Plan (June 2018). However, as the change is an improvement to resilience and the security of supply to customers we do not consider that this is material to the integrity of our drought plan. The change is as a result of a better understanding of the severity of the droughts we have used to determine our system resilience. It does not affect how we would respond to a drought, or the actions we would take during a drought, as set out in our drought plan. We will therefore update our level of service in our drought plan when it is next due for review and update in 2023.

4.7.2 Reference level of service

As required by the Environment Agency WRMP Guideline (July 2018), we have also assessed a reference level of service scenario. This involves setting out the level of service associated with being resilient to a drought with at least an approximate 0.5% chance of annual occurrence (i.e. approximately a 1 in 200 year drought event). In this context resilience means avoiding the use of Emergency Drought Orders that allow restrictions such as standpipes and rota cuts. Details of this assessment are included in **Section 6.1 and 6.2** demonstrate that we can maintain supplies without emergency drought orders in at least a 1 in 200 year drought event.

4.8 Strategic Environmental Assessment

Strategic Environmental Assessment (SEA) became a statutory requirement following the adoption of European Union Directive 2001/42/EC on the assessment of the effects of certain plans and programmes on the environment. This was transposed into legislation on 20 July 2004 as Statutory Instrument 2004 No 1633 – The Environmental Assessment of Plans and Programmes Regulations 2004.

The purpose of an SEA of the WRMP is to:

- Identify the potentially significant environmental effects of the WRMP in terms of the feasible (constrained) and preferred water resources management options being considered;
- Help identify appropriate measures to avoid, reduce or manage adverse effects and to enhance beneficial effects associated with the implementation of the WRMP wherever possible;
- Give the statutory SEA bodies, stakeholders and the wider public the ability to see and comment upon the effects that the WRMP may have on them, their communities and their interests, and encourage them to make responses and suggest improvements to the WRMP; and
- Inform Bristol Water's selection of water management options to be taken forward into the WRMP.

The SEA has been fully integrated with the option selection process to inform the selection of the best value options for both our customers and the environment. The SEA Environmental Report published alongside the draft WRMP in early 2018 presented an assessment of the likely social and environmental effects of the draft WRMP and identified ways in which any adverse effects can be avoided, minimised or mitigated and how positive effects can be enhanced. Following consideration of comments made on the SEA Report during the public consultation on the draft WRMP19 and the subsequent revisions to the WRMP as a result of the feedback received on the draft plan, the SEA Environmental Report has been updated to reflect the updates included in this WRMP and is presented in **Appendix E**.

It should be noted that SEA is an iterative process. The assessment has been based on information available at the time of publication. As further information becomes available and always prior to the implementation of any WRMP option, further review and assessment will be carried out.

The results of the updated SEA assessment of the revised draft WRMP19 are presented in the SEA Environmental Report and associated appendix. Where appropriate, mitigation measures have been identified to prevent, reduce or offset significant adverse environmental effects. These mitigation measures have been taken into account in assessing the residual effects on the environment.

4.9 Habitats Regulations Assessment

Under Regulation 61 of the Habitats Regulations, any plan or project which is likely to have a significant effect on a European site (either alone or in combination with other plans or projects) and is not directly connected with or necessary for the management of the site, must be subject to an assessment to determine the implications for the site in view of the site's conservation objectives.

Therefore, as the competent authority, Bristol Water is required to undertake a Habitats Regulations Assessment screening exercise to assess the potential effects on European sites (also known as Natura 2000 sites) of implementing the WRMP. European sites include those sites designated as Special Areas of Conservation (SAC) under the EU Habitats Directive, Special Protection Areas (SPA) under the Birds Directive, and Ramsar sites under the international Ramsar Convention.

The United Kingdom's exit from the European Union may impact HRA assessment in the future and we will keep a watching brief on any changes. However, no changes to the objectives and requirement of this Directive are anticipated in the short-term and this WRMP has been assessed in full compliance with the existing European legislative framework and the 2017 Regulations.

The HRA has been updated to take account of comments made on the HRA of the draft WRMP during the consultation process and subsequent revisions to the WRMP. The HRA of the WMRP is reported separately from the SEA of the WRMP (at Appendix F), but has been used to help inform the updated SEA, particularly in respect of the potential effects of options on biodiversity.

5 Problem Characterisation

Section Summary

Problem characterisation is a process to assess the complexity and severity of any issues faced by a water undertaker in providing a resilient supply of water in the long term. The problem characterisation we have carried out has informed the techniques and processes used in the WRMP and in accordance with current industry best practice, the process of problem characterisation was guided by an independent and experienced consultancy partner.

Our "problem" was assessed through this investigation as having a “low level of concern” which we believe to be appropriate. This view has been endorsed by our regulators in their comments on the draft WRMP19. On this basis we have selected modelling tools for developing our WRMP including standard current approaches such as Economics of Balancing Supply and Demand (EBSD).

5.1 Overview

The UKWIR methodology *WRMP 2019 Methods – Decision Making Processes: Guidance* (UKWIR 2016) sets out a process of ‘Problem Characterisation’ which is an assessment tool widely adopted by the industry for identifying a water company’s vulnerability to various strategic issues, risks and uncertainties. This enables a company to identify a proportional response in terms of the effort and cost devoted to adopting the selected decision making tools and methods used within the water resources planning process.

The problem characterisation process required the use of expert judgement from across Bristol Water in order to complete the scoring assessment. We therefore commissioned the support of consultants HR Wallingford to plan and facilitate a workshop to take us through the requirements of the problem characterisation process, help us identify the key issues affecting the development of our dWRMP, support us in developing the draft score of the problem characterisation, and identify the evidence which is required to underpin the assessment. Representatives from across the business attended this workshop, including staff from our teams in Water Resources & Environment, Production Asset Planning, Network Asset Planning, and Strategic Planning.

There are two elements to the problem characterisation assessment:

- Strategic needs- a high-level assessment of the scale of need for new water resources and/or demand management strategies (“How Big is the Problem?”) –; and
- Complexity factors– an assessment of the complexity of issues that affect investment in a particular water resource zone or area. (“How Difficult is it to Solve?”).

The full report documenting the workshop and the evidence to support the assessment of the strategic need and the complexity factors is available in **Appendix G**. The overall scores agreed by the participants at the workshop for each stage of the problem characterisation process are set out in **Table 5-1.**

Table 5-1: Summary of Problem Characterisation Results

	Bristol Water Resource Zone score
Strategic Needs	**3**
Complexity Factors (CF) Total score	**9**
A – Supply CF	5
B – Demand CF	2
C – Investment Programme CF	2

The strategic need of Bristol Water was scored as 3, which equates to a 'small' scale problem in the terms of the UKWIR guidance. The overall Complexity Factor was 9, which equates to 'Medium'. The results from the problem characterisation assessment were then combined to understand the level of vulnerability faced by Bristol Water and the resulting complexity of decision making tool ('modelling complexity') appropriate for our WRMP. This is illustrated by placing Bristol Water within the matrix in **Table 5-2** as set out in the UKWIR Decision Making Processes Guidance (2016).

Table 5-2: Outcome of the Problem Characterisation results identifying 'modelling complexity' category

		Strategic Needs Score ("How big is the problem")			
		0-1 (None)	2-3 (Small)	4-5 (Medium)	6 (Large)
Complexity Factors Score ("How difficult is it to solve")	Low (<7)				
	Medium (7-11)		**Bristol Water**		
	High (11+)				

This identified Bristol Water as a 'Low level of concern' and we concurred with this outcome. Under this category 'current' approaches as demonstrated via the Economics of Balancing Supply and Demand (EBSD) should be adequate. If specific complexities are of a concern, then they can be examined at an individual level using 'extended' assessment methods as appropriate. The outcomes of this Problem Characterisation process were used to inform the assessment methods used throughout the development of our WRMP and are referenced where relevant throughout this report.

6 Water Supply

Section Summary

The fundamental principle of water resource planning is the balancing of available water (water supply) with demand. In order to ensure we have the fullest possible understanding of the supply aspects of this balance, we have carefully re-assessed the water supply available to us over the planning period, improving the information available since the previous WRMP14.

Assessment of water resource availability across the planning horizon takes account of sustainability reductions required by the Environment Agency to support sensitive ecosystems; impacts of climate change on reliable water production; allowances for unplanned system outages; and physical constraints such as pump or pipeline capacities.

We have identified some changes as a result: we have reassessed the expected water available to use from existing sources on the basis of more cautious assumptions about the water available in the event of serious drought; we have been able to reduce our projected rate of system outage thanks to investment in addressing issues at one of our water treatment works along with improved equipment reliability; and latest national guidance on climate change impacts has actually slightly reduced our level of concern in the future.

6.1 Deployable Output

6.1.1 Background

As part of developing the supply demand balance, we are required to estimate the yield of our resource zone in terms of deployable output (DO). DO is the output of a commissioned source or group of sources for the design drought that a water resource zone is assessed against, as constrained by:

- Hydrological yield
- Licensed quantities
- Environment (represented through licence constraints)
- Pumping plant and/or well/aquifer properties
- Raw water mains and/or aqueducts
- Transfer and/or output main
- Treatment
- Water quality

As set out in our Problem Characterisation in **Section 5**, we assessed Bristol Water as having a ‘low level of concern’ overall. However, during the problem characterisation process, some concerns were raised relating to the near-term supply system performance due to a limited understanding of the system reliability/resilience under different or more severe droughts than those in the current historic record. We have therefore followed the modelling requirements for a 'conventional' plan using historically based flow time series and, for this WRMP19, we have adopted the latest drought resilience assessment methodology (UKWIR (2017) *Drought Vulnerability Framework*) which we have used to generate a 1 in 200 year drought flow sequence in order to calculate a 1 in 200 year deployable output value rather than using the worst historic drought (HR Wallingford (2018) *Bristol Water WRMP19: Drought Vulnerability Framework and Design Droughts*). This accords with the approaches set out in the UKWIR (2016) *Risk Based Planning* technical guidance. Bristol Water have therefore followed 'Risk composition 1' as set out in the guidance, with added resilience testing of the water resource system for both the baseline and the preferred final planning scenario, using a number of alternative drought scenarios.

In reviewing and updating the DO assessment for the WRMP19, we have used the guidance and approaches set out in the UKWIR (2014) *Handbook of Source Yield Methodologies* as well as the recent UKWIR (2017) *Drought Vulnerability Framework.*

6.1.2 Bristol Water Resource Zone Deployable Output Assessment

The DO of the Bristol WRZ has three separate components which are:

- R01 (supplied by the River Severn, Cam and Frome);
- Groundwater sources in the Jurassic Limestone; and,
- Reservoir system yield (Mendip Reservoirs).

The assessment of the DO of each of these components is set out in the following sections.

R01

The raw water provided by the R01 to supply our largest northern treatment works accounts for approximately 46% of our licensed resource.

The R01 is owned and operated by the Canal & River Trust. The licence for abstraction from R01 is therefore owned by the Canal & River Trust, and the water supplied to Bristol Water's treatment works is provided under agreement with the Trust. The permitted unrestricted abstraction is for an annual average of 210Ml/d with a maximum daily abstraction of 245 Ml/d. The water to supply our water treatment works is abstracted close to Sharpness docks.

The River Severn is supported during dry periods by regulating releases of water from reservoirs in Wales. It is also supported by groundwater via the Shropshire Groundwater Scheme. Periods of river regulation from these sources occur in most years between May and September.

When the River Severn is in a period of regulation, R01 abstraction is restricted to an average of 210Ml/d in any 100 day period. When maximum river regulation is in place, the abstraction must not exceed 210Ml/d on any single day.

Further restrictions on the abstraction are implemented when the maximum tidal level exceeds 9.0m at Sharpness outer dock sill. When this occurs abstraction must not exceed 195Ml/d. When the River Severn flows at Deerhurst are below 2000Ml/d, an abstraction reduction to 195Ml/d may be required at a tidal level of 8.5m at Sharpness, therefore increasing the number of days of possible abstraction restrictions.

To support our WRMP14 an assessment was carried out to determine the likely abstraction pattern for this source during a dry year. This assessment was based on the 1975/76 flow conditions, which is acknowledged as a dry year. There have been no changes to the licence conditions or the assumptions relating to the R01 source for this WRMP. **Table 6-1** sets out the assumptions used to determine the dry year annual average deployable output for this source.

Table 6-1: R01 Deployable output assessment

For a dry year April to March the abstraction pattern is defined as:	
80 days of river regulation conditions	210Ml/d
62 days at maximum regulation (4 months less the days of spring tides)	210Ml/d
45 days drought order (assumed 1975/76 flow conditions)	199Ml/d
28 days at reduced abstraction due to spring tides	195Ml/d
150 days at up to 245Ml/d	216Ml/d
R01 dry year annual average deployable output	**210 Ml/d**

In response to comments on the draft WRMP19 about the drought resilience of R01 supply, we commissioned HR Wallingford to carry out an independent review of the assumptions underpinning the deployable output assessment of this source under a 1 in 200 year drought event (HR Wallingford, 2018). This study concluded that:

- Consultation during spring 2018 with both the Environment Agency and Severn Trent Water did not identify any additional evidence that we could use to assess the likelihood that the River Severn canal supply would be further constrained in a 1 in 200 year drought event
- Reference can be made to drought events within a stochastic flow series for Deerhurst in the lower River Severn developed by Thames Water for its WRMP19 (and made available to Bristol Water). The stochastic flows are typically lower than historic measured flows.
- The 1933-34 drought event flows would be relatively dry compared to the events in the Thames Water stochastic data series. The stochastic data series also showed that even in drought events more extreme than a 1 in 200 year drought, river flows in the Severn would only constrain abstraction to R01 for up to 3 months over the drought event, noting the Hands-Off Flow conditions in place which already constrain the deployable output.

- Based on the limited additional evidence currently available, the potential risk of the Mendip reservoir sources being in a 'severe' drought at the same time as the River Severn is considered very low. If all of Bristol Water's sources were under severe stress (i.e. a 1 in 200 year return period drought) simultaneously, then this is likely to be a drought event even greater than a 1 in 200 year return period drought for the Bristol Water area as a whole.
- No reduction to the DO value used for the draft plan is necessary as it is considered highly likely that 210 Ml/d would be available during the 1 in 200 year drought event.

We therefore continue to report a DO value of 210 Ml/d for R01 supply in this WRMP19.

We will further review the deployable output assessment of this source in a 1 in 200 year drought in advance of the 2024 WRMP, working in dialogue with the Severn Working Group members to ensure an integrated approach to assessing the deployable output of River Severn supplies using the most reliable drought stochastic flow sequences available.

Groundwater sources

The DOs for the Bristol Water groundwater sources have been determined using the standard UKWIR methodology entitled 'A Methodology for the Determination of Outputs for Groundwater Sources' (UKWIR, 1995a). This work was carried out in 1998 and included assessment of the effect of dry periods such as 1975/76 and 1995/96. This methodology has been used to determine dry year annual average DO, and is based on utilising either test pumping data and/or operational data (including drought periods) in the form of water level/output information to assess source performance.

For WRMP24 these groundwater sources will be subject to updated yield assessment which will be based on latest available guidance at the time of the assessment. To account for any uncertainty prior to the update of the DO assessment a greater headroom uncertainty allowance has been applied to the Supply-Demand Balance.

Bristol Water also has a number of spring sources. The deployable output of these sources is considered alongside the groundwater sources, and has also been determined based on the outputs recorded during the dry periods of 1975/76 and 1995/96.

The groundwater and spring source outputs recorded in 1976 demonstrate the conditions under which the company was maximising the supply from these sources at a time when reservoir storage was very low. There has not been a significant dry period worse than 1975/76 or 1995/96 affecting Bristol Water's water supply since this work was carried out, therefore the dry year annual average deployable outputs determined from this assessment are still considered valid. **Table 6-2** summarises the individual groundwater and spring source DO figures for the Bristol Water WRZ, but we have applied an aggregate adjustment to the total DO value as explained below.

Table 6-2: Deployable output for groundwater and spring sources

Source	Type	Deployable output (Ml/d)	Annual licensed quantity (Ml/d)	Constraint
P08R	Spring	3.3	6.8	Dry weather yield
P09R	GW	7.3	13.29	Dry weather yield
P29R	Spring	1.4	2.19	Dry weather yield
P24R	Spring	3.7	6.77	Dry weather yield
P05R	GW	12.40	13.70	Dry weather yield
P23R	GW	2.4	3.29	Dry weather yield
P14R	GW	7.9	15.10	Dry weather yield
P18R	GW	1.6	3.29	Dry weather yield
P30R	GW	2.3	2.60	Dry weather yield
P01-01R	GW	1.3	2.74	Dry weather yield
P31R(P01-02R, P32R)	GW	1.20	2.73	Dry weather yield
P25R	GW	10.10	18.10	Dry weather yield
P33R	GW	7.6		Dry weather yield
P28R	GW	4.7	5.48	Dry weather yield
R24R	GW	0	4.11	Water quality (in Drought Plan)
P34R	GW	0	1.18	Water quality
-	**SUM**	**67.2**	**101.37**	-

The total deployable output of our groundwater and spring sources is therefore determined as 67.2 Ml/d. However, in response to comments on the draft WRMP19 about the drought resilience of the groundwater and spring sources, we commissioned HR Wallingford to carry out an independent review of the assumptions underpinning the deployable output assessment of these sources under a 1 in 200 year drought event (HR Wallingford, 2018). This study concluded that the 1975/76 and 1995/96 drought events used to calculate the DO values may not be as severe as a 1 in 200 drought event, but the scale of the difference in severity is uncertain. HR Wallingford therefore concurs with our proposal to apply an uncertainty allowance of a 10% reduction to the aggregate DO values of spring sources for the 1 in 200 year drought event. We have also continued to include the uncertainty allowance in our target headroom calculation in the same way as we did for the draft plan.

Since publishing our WRMP14, a number of groundwater licences have been revoked (given up). This has not affected the overall DO associated with our groundwater and spring sources because they were reported as ‘unused licences’ in the WRMP14 and therefore had no deployable output allocated to them. A summary of the revoked licences and the reason for them no longer being used is provided in **Table 6-3**.

Table 6-3: Groundwater and spring source licences revoked since WRMP14

Source	Type	Annual licensed quantity (Ml/d)	Reason	Year revoked
P35R	GW	2.74	Water quality	2015
P36R	Spring	1.37	Engineering difficulty	2015
P37R	GW	1.23	Water Quality	2015
P38R	GW	4.93	Water Quality	2015

Reservoir system yield (Mendip Reservoirs)

The DO for the Mendip Reservoirs is calculated using the following widely used assessment tools:

- A mass balance spread sheet modelling approach
- An object orientated resource optimisation model known as Miser

<u>Mass balance model deployable output assessment:</u>

The mass balance model (MBM) is a simplified representation of the WRZ supply system and can be used for testing a range of supply and demand scenarios, including DO assessment. It is used as a higher level planning tool and is complemented by a more detailed WRZ model using the Miser software. The benefits of using the MBM is that it can run a large number of scenarios to understand their approximate effects in order to then identify a smaller number of scenarios for more detailed assessment in Miser. For the purposes of the DO assessment for the draft plan and the WRMP19, the Miser model has only been used to verify the MBM-based assessments and scenarios. Miser will continue to be used to explore the operational optimisation of our supply system, taking account of the DO values from the MBM model.

The MBM includes the dynamic monthly simulation of the reservoir and river abstraction in the south of our water resource zone. The abstraction from the R01 is assumed as a fixed available resource (as determined by the DO assessment set out above). Groundwater resources are split into an assumed 'deep' resource which is constant over time and a 'shallow resource' component which varies by season. The water that is abstracted from the sources is varied using a monthly profile of factors to represent seasonal variations in demand. At each monthly time step, the MBM calculates whether the supply requested can be fulfilled by sequentially moving through the sources in a pre-defined order and updating the system mass balance accordingly.

The MBM contains a batching process function which optimises how much can be abstracted based on a set of user-defined constraints.

Since WRMP14 the MBM has been further developed by HR Wallingford (July 2016) to include the following functionality:

- Enabling the user to select from a variety of input river flow scenarios when setting up the model;
- Allowing the MBM to simulate the water supply mass balance for a specified fixed level of demand (previously it has been designed to optimise only); and,
- Calculating the level of service in terms of the frequency of the application of TUBs restrictions associated with each assessment

These updates have enabled the model to be used more flexibly for both DO and climate change assessments to support the development of our WRMP19.

Miser model deployable output assessment:

The software tool, Miser, is supplied by Servelec Technologies[3], and is an object orientated water resources optimisation modelling platform. It models the behaviour of the system using real data sequences and includes infrastructure constraints (pumping stations, water treatment works and reservoir capacity) licence constraints and levels of service. The model is able to simulate historic inflow sequences with today's infrastructure to understand the maximum demand that can be met by the water resource system. This approach allows the interactions of each of the components of the water resource system to be modelled at an appropriate time step and is generally applied over long periods of hydrological record.

To support WRMP14, Bristol Water commissioned consultants Arup to expand and develop the original Miser model which at that time focused on strategic resources and cost. The model was developed to include all sources, treatment works, key service reservoirs and pumping stations. The demands, seasonal demand profiles and reservoir inflow series were also reviewed and updated where necessary and a Mendip reservoir group component and associated drought control curves were developed to control the operation of the model in line with drought management assumptions and levels of service. Details of this work are documented in Arup's report (October 2012). Bristol Water's Miser model schematic showing the expanded system information is shown in **Figure 6-1**.

[3] https://www.servelec-group.com/servelec-technologies/products-and-services/business-optimisation/miser/

Figure 6-1: ***Bristol Water Miser model schematic*** **[THIS FIGURE HAS BEEN REDACTED FOR THE PUBLIC DOMAIN WEBSITE VERSION]**

In developing the WRMP19 DO assessment, Miser has only been used to verify the DO derived from the MBM, to ensure that the DO assessment method meets the requirements of the technical guidance to define DO in terms of constraints additional to hydrological yield. This work has confirmed that Bristol Water's system is resources constrained, not infrastructure or licence constrained, with the conjunctive use DO value determined using the MBM being replicated in Miser within 0.6%.

DO assumption updates since WRMP14:

In developing the WRMP19 a review of the assumptions used to assess DO in both the MBM and the Miser model was carried out to ensure consistency with our recently updated Drought Plan (Bristol Water, June 2018) and Environment Agency Guidance (July 2018). The main changes to the assumptions used as a result of this review are:

1. **Worst historic drought and 1 in 200 year drought assessments:** The WRMP14 assessed DO against the 1943/44 drought. This is not the worst drought within our historic inflow record and we also did not consider a 1 in 200 year drought event in assessing DO at WRMP14. In order to reflect the requirements in the Environment Agency Guidance (July 2018), the UKWIR *Drought Vulnerability Framework* (2017) and associated technical guidance on DO assessment (UKWIR, 2014) we have updated our DO assessment to both define a DO value associated with the worst drought in our historic record – 1933/34 (as set out in our draft WRMP19 and referenced in this Plan) and a 1 in 200 year drought event (as described in this final Plan). Both changes result in a significant reduction in DO compared to WRMP14.

2. **TUBs savings:** The demand savings used in the WRMP14 DO assessment were consistent with the assumptions set out in our, then current, Drought Plan published in October 2002. However, we have recently reviewed and updated our Drought Plan, including the statutory public consultation process. As a result some small changes have been made to the process by which TUBs are implemented and the water savings associated with this process. The assumptions within the models have therefore been updated to be consistent with those set out in our Drought Plan (June 2018). The effect of this change on DO was minimal.

3. **Emergency Storage:** In WRMP14 an emergency storage volume of 3200Ml was allowed for in the assessment of DO. This was originally determined to inform our first WRMP in 2004 and was based on a 30-day output of 106Ml/d from the Mendip reservoir sources. Since this time, Bristol Water has made several significant changes to our potable water network that has resulted in an increase in resilience, particularly with regard to our ability to transfer water from our treatment works near the R01 in order to protect the Mendip sources. We have also experienced some reduction in demand. As a result of these changes, we have reviewed our emergency storage assumption and updated it to reflect the current anticipated 30 day demand requirement that would need to be met from the Mendip reservoirs during a severe drought situation. This has been determined as a requirement of 2000Ml emergency storage (approximately 66.6Ml/d).

This is considered to be a suitably conservative estimate, as operational experience indicates that during a severe drought situation the actual water requirements from the Mendip reservoirs are likely to be in the order of 50 Ml/d. This change resulted in a small increase in DO.

Historic hydrological record used for DO assessment:

The historic hydrological record used is consistent within both the MBM and the Miser model. It is a composite historic record of monthly flows from 1910 to 2009. The record consists of data derived via the rainfall runoff modelling approach for the period 1910 to 1960, supported by a reservoir mass balance approach to deriving inflows for the remainder of the record from 1961 to 2009. Data from the reservoir mass balance approach was used to calibrate the rainfall runoff model to extend the flow record back to 1910.

The rainfall runoff modelling was carried out using Hysim by WRA (Water Resource Associates) in 2003. An update of the rainfall runoff modelling for the P10R catchment was carried out by Arup in 2012, and this was incorporated into the flow record used for the WRMP14 DO assessment.

The same inflow data set has been used for WRMP19 DO assessment (for the minimum historic DO calculation based on the 1933/34 drought). This is currently the best available information. We have not experienced a significant drought event that would affect the outcome of the assessment since 2009, and therefore this dataset does not have any material implications for the overall supply demand balance assessment or determination of our levels of service. We are committed to carrying out a full review of the inflow record used to support our next WRMP submission in 2024, which will include an update of the inflow record with the inflows from 2009 onwards.

DO for the Reservoir system (Mendip Reservoirs):

By using the MBM and verifying the result within the Miser model the minimum historic DO for the reservoir system (Mendip reservoirs) is determined as 75.36Ml/d based on the 1933/34 historic drought flow series.

This was the DO value reported in our draft WRMP19 in March 2018, but we signalled in the draft plan that we would update the DO assessment to take account of the recently published UKWIR Drought Vulnerability Framework (2017) and updated 2018 guidance from the Environment Agency to reflect this UKWIR work. Responses to our consultation on the draft plan also recommended that we move our DO assessment to reflect a 1 in 200 drought return period event rather than using the worst historic drought flow series. We therefore commissioned HR Wallingford to carry out an assessment of the DO of the Mendip Reservoirs based on a 1 in 200 year return period drought. The HR Wallingford (2018) report for Bristol Water sets out the approach adopted and the resultant DO calculation.

HR Wallingford carried out Extreme Value Analysis (EVA) in line with the methods set out in the UKWIR (2017) *Drought Vulnerability Framework* report, noting the difficulties involved and the underlying uncertainties in the assessed DO values as a result of following these methods. EVA was carried out for selected distributions considering the historic rainfall over 6, 12, 18, 24 and 36 month durations ending in the month of November. Based on the assessment for the 12 and 18 month duration events, the estimated return period for the 1933/34 drought was calculated. The analysis indicated that the 1933/34 drought is notably drier than any other similar duration event in the historic record, and when considering an 18-month duration drought ending in November, is “probably in excess of a 1 in 200 year drought”.

From this EVA work, HR Wallingford used the 1933-34 historic drought event to inform the development of a 1 in 200 year return period design drought for the revised draft WRMP19, adopting a sensitivity analysis approach. This involved intensifying the 1933-34 event (18 month event ending in November) by a ‘deficit factor’ of 1%, 3%, 5%, 7%, 10% and then in 5% increments up to a maximum factor of 40% (of the Long Term Average) and simulating these using five Hysim rainfall-runoff models and the Mass Balance Model.

The results of this sensitivity testing indicated that the DO of the Bristol Water resource system could reduce by 6.7 Ml/d with a 3% deficit factor (345.9 Ml/d) and reduce by 19.6 Ml/d with a 10% deficit factor (333.0 Ml/d). HR Wallingford has recommended that Bristol Water adopts the DO value with the 3% deficit factor as a precautionary basis for the revised draft WRMP19 to reflect a 1 in 200 year return period design drought. 3% LTA equates to the difference between a 1 in 100 and 1 in 200 year drought event as estimated by the EVA findings.

6.1.3 Total DO for the Bristol Water Resource Zone

For the draft WRMP19, the baseline DO for the Bristol Water WRZ was determined for the worse historic drought (1933/34) as the sum of the three components described in Section 6.1.2. This is summarised in **Table 6-4**.

Table 6-4: Bristol Water WRZ component yields and total DO for the draft WRMP19 (worst historic drought of 1933/34)

WRZ component	Yield (Ml/d)
R01	210
Groundwater sources	67.2
Reservoir system (Mendip reservoirs)	75.36
Total DO for Worst Historic Drought (1933/34)	**352.56**

For the final WRMP19, we have adopted the recommended reductions to the groundwater spring sources and the Mendip reservoir sources from the HR Wallingford (2018) report on 1 in 200 year return period design drought assessments and modelling. Using the Mass Balance Model and the reduced DO values for the spring sources and Mendip reservoirs described above, the total DO for the 1 in 200 year drought is assessed as **342.53 Ml/d**, a reduction of 10.03 Ml/d from the minimum historic drought (1933/34) DO value reported in the draft WRMP19 . **Table 6-5** summarises the revised yield components. This revised DO value has been applied to the supply forecast from 2020/21 onwards.

Table 6-5: Bristol Water WRZ component yields and total DO for 1 in 200 year return period drought for the final WRMP19

WRZ component	Yield (Ml/d)
R01	210
Groundwater sources	63.85
Reservoir system (Mendip reservoirs)	68.68
Total DO for 1 in 200 year design drought	**342.53**

The revised DO assessment methodology and resultant value of 342.52 Ml/d has been subject to independent assurance by Atkins (see **Appendix A**). This assurance review concluded that "*the approach used for the revised WRMP was reasonable and we had no significant concerns over the 1 in 200 year DO*".

Both the draft plan DO and the final plan DO values are notably lower than the total DO of 367Ml/d reported in the WRMP14.

6.2 Drought risk assessment and drought resilience

The Environment Agency WRP Guideline (July 2018), and the Defra Guiding principles for water resource planning (May 2016) require water companies to test their WRMPs against more challenging but plausible drought events, in order to assess the resilience of our supplies and identify and respond to any potential vulnerabilities in our water supply systems. If appropriate, water companies can include options within their WRMP to improve the resilience of their supply networks.

In addition, the Environment Agency WRP Guideline (July 2018) requires an assessment to be carried out on a reference level of service to demonstrate how different levels of drought affect our plan. This reference level of service would mean demonstrating resilience to a drought with at least an approximate 0.5% chance of annual occurrence (approximately a 1 in 200 year drought event). In this context 'resilience' means avoiding the use of Emergency Drought Orders (i.e. the use of standpipes and rota cuts). In updated guidance issued in 2018, the Environment Agency asked water companies to carry out this assessment for their revised draft WRMP19 submissions with reference to the UKWIR (2017) Drought Vulnerability Framework.

In order to understand the broader implications of drought risk to society, we have engaged in the Drought Risk and You (DRY) and ENDOWS projects since 2016; these are collaborative research programme exploring the social, economic and environmental impacts of drought across the UK. This has enabled us to build stronger links with academic and research institutions involved in drought, and we will continue this partnership approach.

We have also participated in the steering groups on EA/UKWIR research programmes on drought vulnerability, climate change impacts and resilience measurement.

6.2.1 Drought return period assessment & the reference level of service: draft plan conclusions

In order to meet the requirements of the guidance, for our draft plan we commissioned HR Wallingford to carry out an analysis to understand the context of the historical drought events within our hydrological record in comparison to a 1 in 200 year event (HR Wallingford, September 2017). This assessment looked at the simulated reservoir storage associated with both the DO scenario and the distribution input plus target headroom uncertainty scenario. Annual minimum reservoir storage volumes were extracted from each of these simulations, and extreme value analysis (EVA) undertaken using a generalised extreme value distribution in order to estimate the return period of the simulated reservoir minimum storage. To support this analysis, the historical rainfall record was analysed to estimate the likelihood of occurrence of different durations of long term average rainfall deficits. The overall aim of this analysis was to understand the relative severity of the drought events contained within the historic record, and how they might compare with an estimated 1 in 200 year return period event.

The results of the analysis were used to determine the likely return periods of the droughts within our historic flow record, and also to inform the selection of droughts used to test the resilience of our water supply system to droughts different to those within the historic record.

The chart in **Figure 6-2** shows the results of the EVA of annual minimum reservoir storage under the worst historic drought (1933/34) DO scenario. This analysis shows that the worst drought on record, the 1933/34 drought, is assessed to be a significant outlier to the 5th and 95th confidence intervals up to a 1 in 1000 year event. The extreme outlying nature of this event suggests that it may have a different mechanism for its generation when compared with the other droughts assessed. Examination of the system response to the 1933/34 drought shows that it is the only multi-year event in the DO simulation where the combined reservoir storage does not refill during the winter period. This results in the drawdown in summer 1934 being more severe because the starting level is lower than any other year. This is shown graphically for the modelled historic 1933/34 drought in **Figure 6-3**.

Figure 6-2: Return period plot of annual minimum reservoir level for a DO demand scenario (GEV, Generalized Extreme Value (HR Wallingford, 2017)

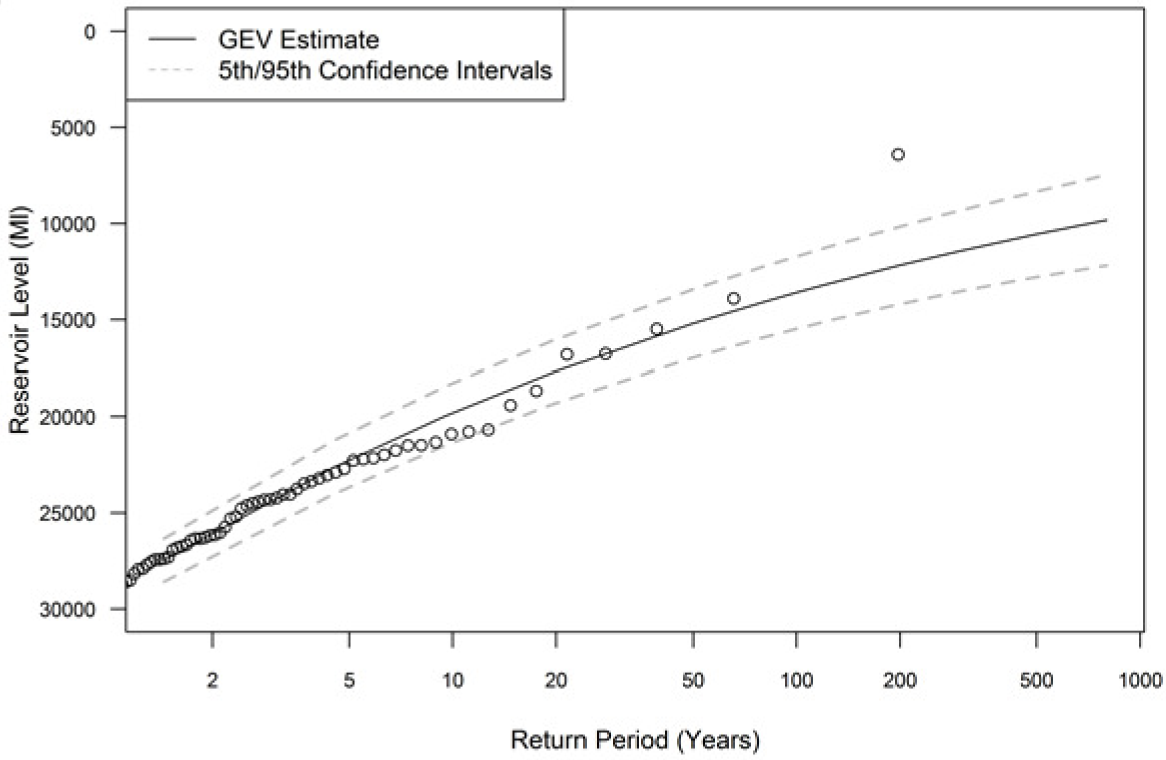
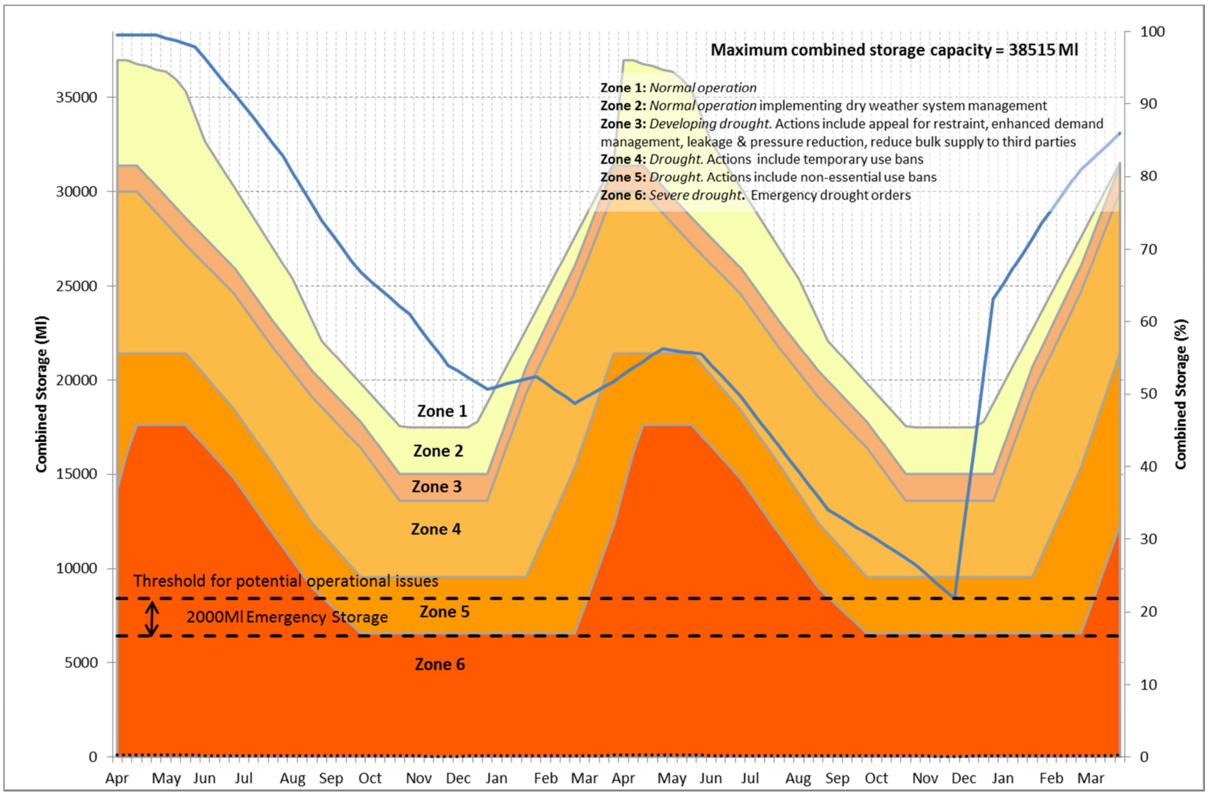


Figure 6-3: ***Modelled reservoir drawdown under the 1933/34 DO scenario (worst historic drought)***



The modelled drawdown for the 1933/34 drought in **Figure 6-3** illustrates that under this worst historic scenario, combined reservoir storage does not enter drought management zone 6, where Emergency Drought Orders would be put in place in line with our Drought Plan 2018. This demonstrates that Bristol Water is likely to be resilient to a drought with at least a 0.5% chance of annual occurrence (1 in 200 year drought event) under the base year planning scenario.

Our technical assurance with Atkins of the draft plan indicated that further assessment would be appropriate for the revised draft plan in order to improve the certainty over the drought scenarios. We also discussed our proposals to update the assessment with the Environment Agency in light of the publication of the UKWIR (2017) report and associated updated Environment Agency guidance. This further work is discussed in **Section 6.2.2** below.

6.2.2 Drought return period assessment & the reference level of service: revised draft WRMP19 conclusions

As described in Section 6.1, we commissioned HR Wallingford to review the EVA to both better determine the likely return period of the 1933/34 worst historic drought event and develop a 1 in 200 return period design drought for updated DO calculations in accordance with the latest UKWIR (2017) methods. The HR Wallingford (2018) report shows that the updated EVA carried out using the UKWIR (2017) methods provides similar conclusions about the 1933/34 drought as described above for the draft plan. Four selected extreme value distributions were considered, with one discounted (Peak over Threshold Gumbel) due to a poor fit to the data. The other three distributions showed a range of return periods for the 1933/34 historic drought event of 18 months duration ending in November of between 256 years and 601 years, giving further confidence that the 1933/34 drought event is likely to have a return period greater than 1 in 200 years.

Development of the 1 in 200 year design drought (described above in Section 6.1) and modelling of the associated flow sequence using the MBM model shows that, whilst the DO value is reduced by 10.03 Ml/d, combined reservoir storage does not enter drought management zone 6, where Emergency Drought Orders would be put in place in line with our Drought Plan 2018. This demonstrates that Bristol Water is resilient to a drought with at least a 0.5% chance of annual occurrence (1 in 200 year drought event) under the base year planning scenario. There are no changes to the level of service arising from the updated assessment.

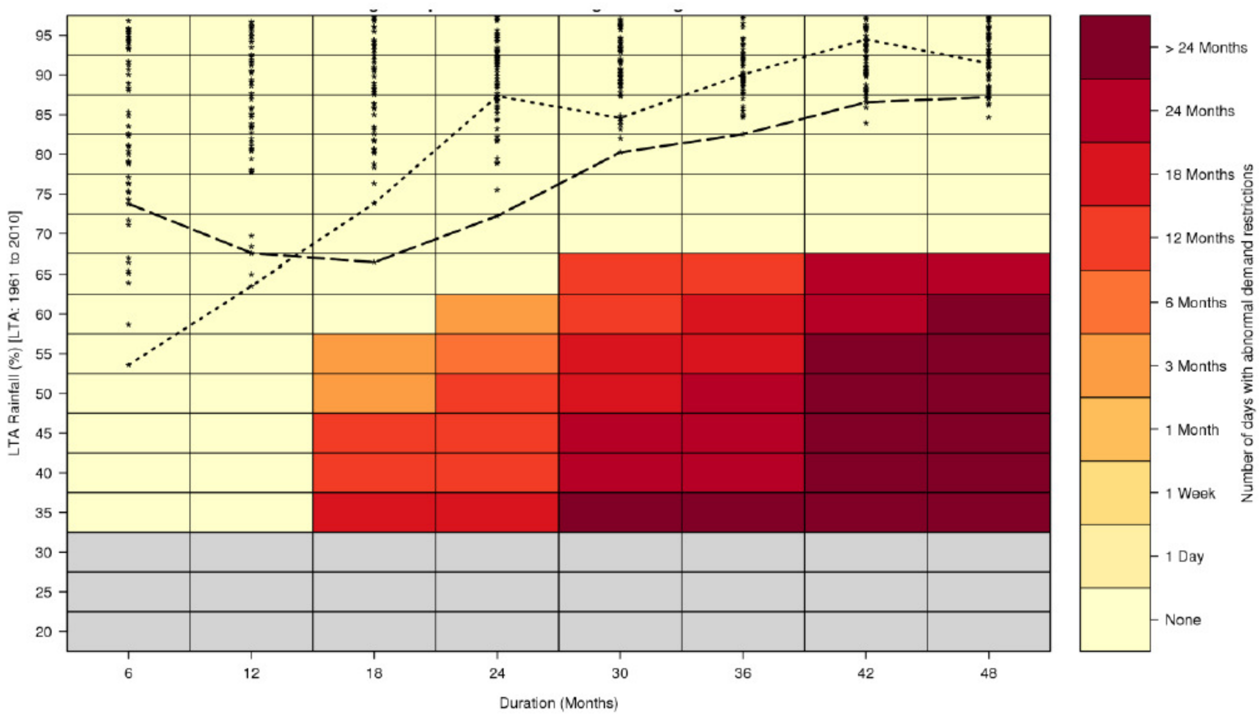
6.2.3 Drought Vulnerability Framework Assessment

The UKWIR (2017) *Drought Vulnerability Framework*, in which Bristol Water was part of the steering group, includes guidance on preparing a “drought response surface” which is a method that can be used to summarise the systematic testing of a supply system to a range of drought events. We commissioned HR Wallingford to prepare an updated drought response surface, taking account of the final UKWIR methodology and the updated EVA as described earlier in Section 6.1.

The drought response surface plots display the drought characteristics of duration on the x-axis and intensity (i.e. % of LTA rainfall) on the y-axis. The chosen system performance metric is represented using coloured squares. Each square represents the water supply system response to a particular combination of drought event duration and intensity. Grey regions of the plot represent scenarios that have not been assessed due to being significantly beyond those that might be expected based on the long-term historic record.

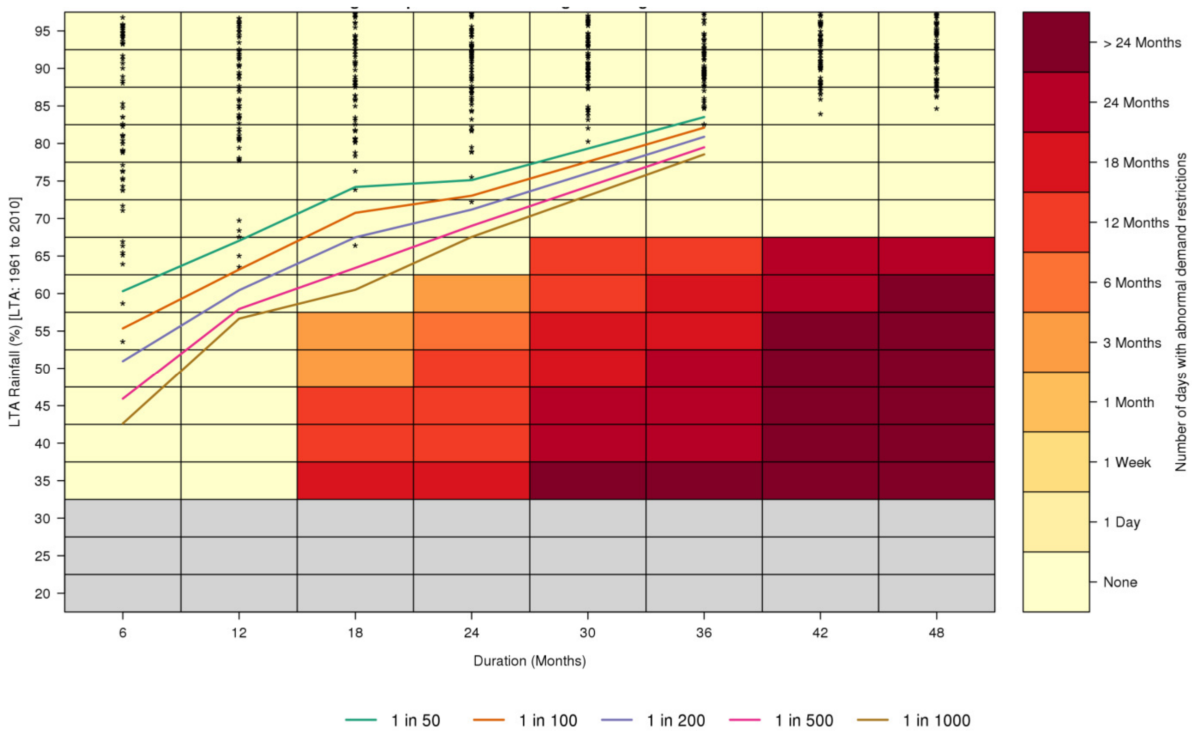
The historical rainfall from the observed record have been analysed and are shown as black stars on the plot to provide a useful historical context to the drought scenarios. **Figure 6-4a** provides the drought response surface plot for the base year with the profile plots of the 1933/34 and 1921 historic drought events shown as dashed and dotted lines, respectively. Figure 6-4b provides the same information but with the likelihood contours based on the most conservative distribution return period estimates.

Figure 6-4a: Drought response surface plot for base year with 1933-34 (dashed line) and 1921 (dotted line) historic drought events



These plots show that the Bristol Water supply system is resilient to drought events. The system can withstand single year drought events, coping with 12 month events of 35% of LTA rainfall without effect, well beyond the historic record and the 1 in 1000 likelihood contour. The supply system is more sensitive to the 18 and 24 month duration droughts, with impacts realised at 55% and 60% of LTA rainfall, respectively. This reflects the fact that, under such conditions, reservoir refill is limited in the winter months and not fully recovering before the drawdown in the following summer. However, the drought response surface plots clearly show that the thresholds at which impacts are realised are beyond that experienced in the historical record and the estimated likelihood contours for the 1 in 1000 year return period drought. For the critical 1933-34 drought, the rainfall would need to be 10% of LTA or lower to result in impacts being realised.

Figure 6-5a: Drought response surface plot for base year with likelihood contours



6.3 Reductions in Deployable Output

6.3.1 Sustainability reductions

P25R& P33R licence reduction

For more than twenty years we have worked with Wessex Water and the Environment Agency to help resolve a low river flow issue caused by Wessex Water's abstractions in the Malmesbury area. During a dry summer, these abstractions can cause very low or even zero flows in the local river and in order to help mitigate this impact we voluntary agreed in the 1990's to reduce our pre-existing abstraction at P25Rand P33R (which have been operating since the 1930's) in order for Wessex Water to pump water directly into the river affected by their abstraction; a process known as 'stream support'. Although effective, this early approach did not entirely resolve the situation and low river flows were still noted in the area so we have continued to work with Wessex Water and the Environment Agency to identify the best way to resolve this problem.

We have now agreed with these partners that we will formalise our existing voluntary abstraction reduction in order to maximise the water available for stream support by Wessex, and we will further reduce our abstraction when ground water levels in the area are particularly low. This further reduction in abstraction is being supported by a transfer from Wessex from their own resource system. We consider that this responsible partnership approach, which ensures protection of the environment while enabling a neighbouring company to provide a resilient supply to their own customers, is an outstanding example of the work that water companies and environmental regulators in the UK do to protect the environment and provide the reliable supply of water needed by our customers. Further information can be found in Arcadis (2017).

Water Industry Environment Programme (WINEP)

Under the Environment Agency's WINEP 2018 (WINEP Version 3 programme), a number of our abstraction licences and associated sources have been identified as requiring further investigations relating to their long term sustainability. As all the licences identified are currently at the 'investigation' stage, no specific licence reduction requirements have been identified for WRMP19. Therefore there is no explicit effect on source deployable output and water available for use. Details of the WINEP programme and how we have accounted for the uncertainty around the licences that will be investigated, are provided in **Section 9**.

6.4 Climate Change

Allowances for climate change impacts result in a reduction in baseline DO under the best estimate scenario. The uncertainty around the potential extent and timing of the effect of climate change is included within the headroom uncertainty assessment.

Since WRMP14, there have been no further UKCP scenarios released; however, the Environment Agency guidance relating to which UKCP09 scenarios to use has been changed. This has resulted in the need to update the climate change assessment to reflect the new guidance. Full details of this assessment are provided in **Section 10**.

6.5 Outage

Outage is an assessment of the risk of temporary or short term losses of supply. The outage allowance assessment carried out to support Bristol Water's draft WRMP is reported in detail in a separate supporting report, *Bristol Water Outage Assessment for WRMP19 – Outage Summary Report* (Amec Foster Wheeler August 2017). A summary of this assessment is provided in the following sections along with details of the minor revisions made to the outage assessment following publication of the draft WRMP to take account of the changes to the deployable output values.

6.5.1 Background

Outage is defined as a temporary loss of DO in a dry year due to planned and unplanned events. An allowance for outage is required in the WRMP supply demand balance in order to recognise that at any given time some assets will temporarily be out of action for one reason or another.

In our WRMP14, an assessment of the outage allowance was based on a five-year rolling average figure, using records over 2008-2012, and resulted in an outage allowance of 17Ml/d.

For this WRMP we reviewed and updated our approach to outage assessment in accordance with the most recently released guidance (Environment Agency (July 2016) *WRMP19 methods: Outage allowance – Outage in water resources planning).* This guidance recommends developing an outage allowance following the principles within the UKWIR report on outage allowance for water resources planning (UKWIR, 1995). We therefore commissioned consultants Amec Foster Wheeler to support us in developing our approach to outage assessment to be aligned with the UKWIR (1995) methodology.

6.5.2 WRMP19 Approach

Data gathering and collation

We collated outage data for the five year period from 1 April 2011 to 31 March 2016 from our SCADA telemetry system. This data was screened using an outage threshold for each of Bristol Water's water treatment works (WTW) to identify the outage days (i.e. the number of days on which the WTW output was less than the outage threshold value). Additional information from our daily WTW reports/logs was used to identify the cause of the outage and determine if it was either a planned or unplanned outage. Each unplanned outage was then allocated to one of the specific outage categories set out in the UKWIR (1995) methodology as follows:

- Pollution of source
- Turbidity
- Nitrate
- Algae
- Power failure
- System failure

This data was used to develop a list of outages for each WTW over the 5-year assessment period. The data was further screened and validated via a workshop with the Bristol Water Area Operations Managers and Water Resources staff to assess the outages identified, confirm them as legitimate outages, and that they are reflective of how such outage events would be managed under a dry year scenario. This review also included a sense check against any effects of recent or future investments that could alter the frequency and magnitude of specific outage events captured in the database.

Method review and selection

Data availability is critical to selection of the appropriate modelling methodology. Amec Foster Wheeler reviewed the data collated in the context of the Environment Agency Water Resources Planning Guideline (April 2017) and the recommended methodologies for determining outage allowance set out in the WRMP19 Methods (2016) UKWIR guidance.

Taking into consideration the period of outage data record available, and that Bristol Water's 'modelling complexity' category identified via the Problem Characterisation process was 'Low level of concern' (see **Section 5**), it was recommended that Bristol Water follow the 'Basic Reference method' for our outage assessment. This method uses the UKWIR (1995) methodology and involves evaluating historical outage records and estimating values to use for planning. A Monte Carlo modelling tool was therefore developed by Amec Foster Wheeler, and used to assess the probability of a potential future reduction in deployable output occurring as a result of unplanned outage events.

Modelling

The dry year outage assumptions developed from the data collation exercise, were processed using the Monte Carlo Crystal Ball[4] modelling software. Triangular distributions were developed from the outage data collated to reflect the likely duration (in days), magnitude (the proportion of 'normal' daily output which is lost) and frequency of outage events under each outage category at each water treatment works. The triangular distributions are developed by identifying minimum, best estimate and maximum values. For each water treatment works, at the water resource zone levels, outage is calculated as:

$$\frac{\text{Duration (d)} \times \text{Magnitude (\%)} \times \text{Frequency}}{365.25} = \text{Outage (\% Production)}$$

The model runs 1000 iterations of the above calculation for each outage assumption by drawing randomly from the input distributions. A cumulative distribution function (CDF) of outage is calculated from the individual outage results. Outage is calculated by apportioning the treatment works outage according to the DO of each treatment works. A risk percentile is then chosen from the CDF and used as an outage allowance for the WRMP.

Results

We have fifteen water treatment works across our single water resource zone. Water is abstracted from various different sources (groundwater, river abstraction, reservoirs, spring sources, or a combination of these). The outages experienced at each water treatment works are variable. This is largely dependent on the type of source, the location of the source and the strategic importance of the source within the overall network. Water treatment works that are classed as critical are maintained to a level where they have zero outages because any issues on site are fixed immediately. **Table 6-6** summarises the total outages (in days) experienced for each year of record, and the identified cause of these outages.

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[4] Oracle Crystal Ball Software:
http://www.oracle.com/us/products/applications/crystalball/overview/index.html

Table 6-6: Total outage (in days) for all water treatment works*

Year	Planned Outage	Power Failure	System Failure	Turbidity	Total Outages
2011/12	4	2	61	50	117
2012/13	29	0	39	180	248
2013/14	1	0	81	26	108
2014/15	32	0	13	34	79
2015/16	7	4	110	20	141
Total	73	6	304	310	693

*There were no historic records of source pollution, nitrate or algae outages (less than 3 months)

In order to determine a final outage volume to be included within the assessment of the supply demand balance, the outputs from the Monte Carlo assessment were reviewed in the context of the level of risk we intend to take relating to planned outage occurrence. The results for different levels of percentile risk are presented in **Table 6-7**. This assessment has been refined and updated since the draft WRMP19 was published to take account of the changes reported earlier to deployable output, but the changes are no greater than a 0.04% increase (as % of deployable output) and a 0.15 Ml/d reduction (outage value) across each percentile risk.

Overall the outage is quite low in the context of the UKWIR (1995) definition of outage. It is also notably lower than the outage allowance of 17Ml/d used in the WRMP14 supply demand balance. In order to check the new outage assessment approach with the method used for the WRMP14, a cross-check was carried out using the same averaging method on the updated data set that was used to derive the WRMP14 outage result, therefore providing a like-for-like comparison between the two data sets. Using the same averaging method an outage percentage of 0.7% (2.4Ml/d) is calculated (based on the updated deployable output values for the WRMP19). This demonstrates that there was significantly less outage in the 2011-2016 period compared to the 2008-2012 period. This particularly reflects the investment we have made to address and eliminate a relatively high outage risk at one of our treatment works in recent years, along with ongoing activities to enhance proactive maintenance to reduce unplanned outage events. We are therefore satisfied that the updated outage assessment reflecting the latest guidance and methodologies is representative of the current outage risk within our water resource zone

Table 6-7: Bristol Water outage assessment Monte Carlo analysis results

Percentile risk (%)	Outage (% of deployable output)	Outage (Ml/d)
50	1.02	3.43
60	1.09	3.65
70	1.16	3.91
80	1.26	4.22
90	1.40	4.71
95	1.53	5.12
100	2.16	7.23

The figure corresponding to the 95th percentile (as shown in **Table 6-7**) has been selected to represent the outage in the Bristol Water resource zone. This is calculated as 1.53% of deployable output (5.12Ml/d). This value represents the level of risk we consider is acceptable to plan for in the context of the relatively low actual levels of outage experienced across our water resource zone.

There are no significant developments planned for our supply system that are likely to have a notable effect on outage over the planning period, therefore we have determined that it is appropriate to use the same percentage outage allowance for all 25-years in our planning horizon. An assessment of actual outage is made on an annual basis as part of the WRMP Annual Review process. This will identify any significant variations in the amount of outage being experienced compared to the forecast allowance.

6.5.3 Opportunities to reduce outage

The EA Water Resources Planning Guideline (July 2018) states that water companies should consider options to reduce outage where there is a supply demand balance deficit, or where it makes sense to do so. Our WRMP supply demand balance assessment indicates that we will have a small supply deficit occurring within the 25-year planning period, but we are currently in surplus. As part of the options appraisal process for the WRMP (see **Section 13**) we have considered the viability of options to reduce outage, particularly in the context of a catchment management approach. However, the low volume of outage currently experienced, and how this is distributed across our fifteen water treatment works, means that the number of quantifiable options currently available to reduce outage still further is minimal.

6.6 Raw and Potable Water Transfers and Bulk Supplies

Bristol Water operates a number of small potable water transfers across areas of the company's boundary with other water companies. These include small transfers from Wessex Water for supply to approximately fifty properties in the Frome area (DYAA of 1.13 Ml/d) and an historic transfer to Severn Trent customers in the area of P08R (this transfer is no longer in use).

Raw water customers comprise a mushroom growing facility in the Mendip hills and historic supply of untreated water from the R01 to industrial customers in the Avonmouth area (this supply is currently not in use). The licensed volume is 0.07 Ml/d.

The largest transfer currently operated by Bristol Water is a potable supply to Bath, which can provide a DO up to 11.37Ml/day of treated drinking water via a connection from the Bristol Water network to the distribution network operated by Wessex Water. Historically, the supply to Wessex Water is below the 11.37 Ml/d DO. There is also an additional treated transfer of 0.33 Ml/d (DYAA) to Wessex Water.

In our draft WRMP19, we included as a feasible option (Option R32-02) an action to agree a reduction to the export to Wessex Water for the supply to Bath. A reduction of 6.37 Ml/d was selected for inclusion in our draft WRMP19 preferred programme for the final two years of the planning period (2043-44 onwards) to maintain the supply-demand balance. Since publication of the draft WRMP and taking account of feedback received on this measure during the consultation on the draft plan, negotiations have been continuing with Wessex Water about future changes to the contractual volumes for the export. Without prejudice to contract discussions, we have now agreed with Wessex Water that, from a water resource planning and operational management perspective, for the purposes of calculating Water Available For Use the baseline export volume that both companies will report will be 11.37 Ml/d for the period to 2024/25, followed by a reduction to 4.4 Ml/d for the remainder of the planning period to 2044/45. These agreed changes are reflected in the baseline supply forecasts in the final plans of both water companies.

We have also agreed that Bristol Water will not consider any option to reduce the volume below 4.4 Ml/d without full engagement with Wessex Water, reflecting concerns that the loss of this transfer could reduce the resilience of water supplies for Wessex Water and in light of the national policy direction to achieve robust water transfers between water companies. As a result of this agreement, option R32 (all variants) has been removed from the feasible list of options.

6.6.1 Raw Water Transfers within WRZ

We operate a number of raw water transfers within our supply network. The majority of which are supplied directly to water treatment works. A small number of transfers are between water bodies and catchments. Some of these transfers shown are used very infrequently, but include:

- P42R Lake to P16R Tanks and P10R Reservoir
- P10R Reservoir to P16R Tanks and P42R Lake
- R03 to P39R
- P39R to P16R Tanks, P42R Reservoir and Ubley Hatchery
- The R14R to P10R Reservoir.

Raw water quality is monitored via Operational Monitoring which is used to inform operational procedures and if poor water quality is detected, the transfer of water is halted. Some high risks sites have specific treatment to manage the risks of poor water quality, for example the R14R abstraction is treated via Actiflo[5] enhanced clarification system prior to discharge into P10R Reservoir. The system is designed to primarily remove phosphorus but also reduces the risk of transferring invasive species.

[5] Actiflo is a process where a coagulant is added to the raw water as a processes to remove particulates and pollutants

P16R Tanks are supplied by a number of raw water sources but predominantly P42R and P39R Reservoirs. These tanks are short term holding tanks holding water prior to treatment at P16R treatment works and are not considered to be WFD water bodies. During 2016, following issue of the draft version of our NEP phase 1 report into P16R 3 reservoir, the Environment Agency reviewed the WFD status of P16R Reservoir No. 3 and concluded that the reservoir should no longer be a Drinking Water Protected Area, negating the requirement for it to be considered a WFD water body.

In AMP6 we have assessed the risk of our raw water transfers on the spread of invasive species. This work will continue into AMP7 where we will investigate the presence of invasive species at these locations. The outcome of this work may recommend mitigation measures to manage this risk in the future. Further details are provided in our Business Plan.

6.7 Operational Use and Process Losses

6.7.1 Raw water losses, treatment works losses and operational use

Raw water losses, treatment works losses and operational use of water is the sum of:

- Raw water lost or used as part of transmission (including aqueduct losses and draining down of mains and reservoirs for maintenance);
- Storage losses (including seepage, discharges and evaporative losses);
- treatment process; and,
- Operational use of water (both raw and treated).

Some of these items can be measured directly (i.e. flows into and leaving a treatment works), but others such as raw water losses will be estimated from a balance of flows and subject to some error. In most cases, the water ‘lost’ flows back to the source resulting in a negligible effect on yield.

Raw Water Losses

We measure raw water losses as the volume of water lost between abstraction from our raw water sources and transported to the head of a treatment works. During AMP6 we have been implementing a programme of work to install additional flow monitoring across our raw water system. As we deliver this programme, we are progressively increasing the accuracy of our raw water losses assessment.

Treatment Works Losses

Treatment works losses are defined as the losses that occur between the inlet to the treatment works to the outlet of the treatment works (our distribution input flow meter), taking into account any volumes of water which are recirculated to the head of the works as “supernatant” to avoid double counting. To ensure data accuracy, there is an ongoing programme of work whereby desk studies are carried out to assess the flow meters within a treatment works, comparing them to the next upstream and downstream flow meter. Where a discrepancy of greater than 5% exists, it is escalated for further investigation on site. In addition, flow meter totaliser readings are submitted from site weekly, and these figures are compared to telemetry to verify that what telemetry is reporting is correct. We have also carried out maintenance investment at a number of treatment works to address losses over the past few years.

Operational Use

Operational use of water is split between raw water and treated water operational use. Raw water operational use is calculated as the volumes of water which are used to supply our fish hatchery, which is approximately 3.5 Ml/d.

Baseline Raw Water Losses, Treatment Works Losses, Operational Use Volumes

In our draft WRMP19, we reported that our combined baseline raw water losses, treatment works losses and operational use amounted to a total of 29.09 Ml/d and this was the baseline value for the 25-year planning period. Due to the investment in metering and work to reduce treatment works losses in the last few years, we have seen a reduction in the total volume of losses and operational use during 2017/18 to 20.27 Ml/d, as reported in our 2018 WRMP14 annual review submission (June 2018). This value of 20.27 Ml/d is now also reported in our fianl WRMP19 baseline supply forecast from 2017/18 to 2044/45. We continue to include an option to reduce raw water losses and treatment works losses in our WRMP19 (see Section 13).

6.8 Zonal Summary of baseline Deployable Output and Water Available For Use (WAFU)

Table 6-8 summarises the results of the baseline supply calculations for the Bristol Water WRZ for the 2017/18 base year and the first year of the planning period in 2020/21, including our best estimate of the effects of climate change.

Table 6-8: Summary of baseline supply side components for 2017/18 base year and first year of the planning period in 2020/21

Year	Total DO of own sources Ml/d	Reductions in DO* Ml/d	Outage Ml/d	Water Available For Use-Own Sources (Ml/d)	Balance of Raw and Treated Water imports/exports (Ml/d)	Total Water Available For Use (Ml/d)
2017/18	352.56	-34.68	9.91	307.97	-6.23**	301.74
2020/21	342.53	-34.99	5.12	302.42	-10.82 #	291.60

*(climate change, sustainability changes and Treated Water Losses & Operational Use)
** Actual volumes as reported in WRMP14 Annual Review (June 2018)
# Agreed contractual volumes

6.9 Drinking Water Quality

Excellent water quality is fundamental to providing the level of service our customers expect from us. Our aim is always to supply water that is not just safe to drink but meets the taste and aesthetic qualities that our customers expect from us every day, all year round. We achieve this using advanced treatment processes and a team of highly trained staff. This is reflected in our water quality results, with over 99.9% of the 120,000 drinking water tests carried out each year being compliant with UK Drinking Water Inspectorate (DWI) and EU drinking water standards. We continue to invest in new treatment processes and renovation of water mains. Our work with partners in our source catchments, such as delivery of the Mendip Lakes Partnership project, ensures this high standard of water quality is maintained.

Bristol Water complies with section 68(1) of the Water Industry Act 1991 that covers our duty to supply wholesome water. Wholesomeness[6] requirements are set out in the Water Supply (Water Quality) Regulations 2000 (in England) and the Water Supply (Water Quality) Regulations 2001 (in Wales), and associated amendments.

This following section provides an overview of the key ways we protect water resources. These include operational monitoring of raw water, working with farmers to improve water quality in our reservoirs and sources, to sampling the compliance at customer taps. Risks are identified and resolved via the Drinking Water Safety Plans (DWSPs[7]). Drinking water compliance standards are regulated by and reported to the Drinking Water Inspectorate (DWI).

6.9.1 Catchment Management

We work alongside farmers and other stakeholders to implement catchment management to manage the risk of raw water quality. This not only provides resilience benefits from reduced outage but also provides a sustainable and cost-effective approach in comparison to traditional treatment approaches.

We have also worked with the Environment Agency to identify catchments where pollution is likely to require increased levels of treatment, and we are working across these catchments to control and where possible reduce these risks.

[6] Regulation 4 - water is wholesome if it contains concentrations or values in respect of various properties, elements, organisms and substances that do not contravene the prescribed maximum, and in some cases, minimum concentrations or value.

[7] A Drinking Water Safety Plan (DWSP) is the most effective way of ensuring that a water supply is safe for human consumption and that it meets the health based standards and other regulatory requirements. It is based on a comprehensive risk assessment and risk management approach to all the steps in a water supply chain from catchment to consumer.

Metaldehyde

Metaldehyde is the active ingredient in conventional slug pellets and is used widely by the agricultural industry and domestic growers to protect crops and seedlings. Metaldehyde is very difficult to remove from raw water to meet the required drinking water standards. Following a trial undertaken in 2013 to encourage the substitution of Metaldehyde with ferric phosphate, we have implemented a catchment management strategy with farmers during AMP6. This has been successful and we plan to continue the scheme in AMP7 (2020-25).

The Mendip Lakes Partnership

P39R, P42R and P10R Reservoirs have in recent years recorded increasing frequencies of algal blooms. These algae make the water more difficult and expensive to treat resulting in increased costs. Blue green algae can pose a public health risk, and may also adversely affect the taste and odour of treated water. The reservoirs are all designated as Sites of Special Scientific Interest (SSSI), and P39R Reservoir is also a Special Protection Area (SPA) under the Birds Directive, so we have a responsibility to ensure their condition is maintained appropriately from an ecological perspective. The reservoirs are also water bodies under the Water Framework Directive; to be assessed at ‘Good’ status, nutrient concentrations must be reduced from their current levels.

In 2014, Bristol Water set up the Mendip Lakes Partnership to bring together organisations working to reduce the impacts of diffuse pollution from agriculture. The Partnership is working with farmers across the P42R, P39R and P10R Reservoir catchments to protect and improve water quality in the reservoirs and associated watercourse, and to enhance wildlife habitats. As part of the project, Bristol Water has implemented a comprehensive water quality monitoring programme so that we can understand risk areas and identify improvements over time. Improved water quality will result in lower treatment costs and protection of the designated features of the reservoirs. It will also help to improve the resilience of our raw water supply should climate change or socio-political factors affect land use and soil and water interactions in the future.

6.10 Upstream Competition

We have reviewed our obligations regarding water trading and have produced a trading and procurement code for approval by Ofwat. We published our market information tables in 2018 in respect of the draft WRMP19 and will update these tables within 1 month of publishing our Final WRMP19. Our current appraisal is that we do not have any new obligations under reforms on water trading as we do not have any new or planned transfers to or from our single water resource zone within the planning horizon to 2045.

7 Water Demand Forecast

Section Summary

The west of England is a rapidly-growing area and by 2045 the population we supply will have risen from 1.21 million at present to approximately 1.48 million people. Nonetheless, our projected demand for water is not forecast to grow by the same extent, thanks to continuing action to reduce leakage, increasing rates of water metering (which helps reduce demand for water) and improvements in household water efficiency.

We have developed detailed per person consumption forecasts for household customers, taking account of forecasts of demand for various water uses around the home such as washing, washing machines and dishwashers, as well as the impact of climate change on demand for water.

A set of non-household demand forecasts has been provided covering a 25-year period. This study and analysis investigated a series of methodologies from a high-level trend analysis, to finer analysis by consumption band and industry code. Several different trend-based forecasts are used to estimate future non-household demand. Relationships with economic factors such as population, unemployment and GDP were also considered and it was shown that there is a moderate relationship between total non-household demand and employment. This is also factored into the non-household demand forecast.

Based on these projections, we have identified that total water demand will rise only gradually by just 4.4 Ml/d across the 25 year planning period from 281.4 Ml/d at 2017/18 to 285.8 Ml/d at 2044/45.

7.1 Introduction

The EA Water Resources Planning Guideline requires water companies to use assessment methods for supply and demand analysis that are appropriate to the level of planning concern in each water resource zone. As identified via the Problem Characterisation process in Section 5, our 'modelling complexity' category showed a 'Low level of concern'. An assessment of suitable methods for demand forecasting was carried out, and details of the selected assessment method for each element of the demand forecast are set out below. We commissioned Artesia Consulting (2017a and 2018) to support the development of our demand forecasts

7.2 Base Year

The base year selected for developing the WRMP demand forecast is 2017/18 using the annual outturn data reported in the WRMP Annual Review for 2017/18 (AR18). Demand forecast components are therefore reconciled to the observed levels of consumption within the base year. Analysis of the rainfall, temperature and associated distribution input against the long term averages indicated that 2017/18 was slightly above average in terms of rainfall which counter-acted the effect of a predominance of above-average temperatures over much of the year. Overall, demand was characterised as being higher than expected in a “normal” year but lower than in a “dry year” that we use for assessing the supply-demand balance.

The UKWIR methodology *WRMP19 Methods: Household Consumption Forecasting* (2015) has been used to derive normal year annual average (NYAA) and dry year annual average (DYAA) factors to adjust the base year forecast. The dry year factor was calculated to be 1.044, measured household normal year factor is 0.940 and the unmeasured normal year factor is 0.982.

7.3 Population, Properties & Occupancy

7.3.1 Methodology

In accordance with the EA Water Resources Planning Guideline, our approach to developing population, property and occupancy forecasts for the draft WRMP19 followed the methodology set out in the UKWIR (2015) guidance *WRMP19 Methods: Population, Household Property and Occupancy Forecasting Guidance Manual*. This approach recommends the data should be based on local plans published by the local council or unitary authority, where the data are available. Where data are not available, companies are recommended to use their own property forecasts.

A number of data sets have been used to develop the population and property forecasts. The two main methods are via the use of relevant local authority information, termed ‘plan’ data, for local authorities within the Bristol Water supply area, and via official statistics from the Office of National Statistics (ONS), termed ‘trend’ data.

The outputs from this analysis were incorporated within the household consumption forecast model and report. Within the model there is a calibration step to ensure that the final population and property forecasts are in-line with the reported figures from the WRMP Annual Review 2018 (AR18). The trends from the figures reported were then used to forecast from the base year reported figures.

Details of the analysis to develop the population and property forecast are provided in the following sections.

Local Authority plan-based forecasts

The plan-based approach used data collated from the local authorities within the Bristol Water supply area. Each of the nine local authorities responded to a data request for population and property forecast information with differing levels of detail. Population figures are lacking across many of the local authorities, and this likely to be due to many of them directly referencing Office of National Statistics figures rather than providing an alternative set of figures.

Some of the local authorities provided shorter horizon forecasts than required for our WRMP assessment. In order to provide a full estimate, the missing data points were linearly projected forward to cover the full WRMP planning period up to 2044/45. This estimation step was validated by comparison to the ONS data.

Office of National Statistics (ONS) trend-based forecasts

Trend-based analysis used data from the Office of National Statistics (ONS). For both population and households, a long term trend was available at the local authority level.

An assumption was made that households have a similar split in terms of where they are located within the local authority compared to the population that resides within these households (i.e. the number of persons per household). Therefore, the local authority-level predictions of population and households were multiplied by the percentage of each of the local authorities within the Bristol Water area. The household and population trends analysed over time were then summed annually to provide data for the Bristol Water area.

Household Property Forecast

Table 7-1 show the projection for household numbers annually to 2044/45 using both the 'trend' based and 'plan' based methodologies. The projections are similar. Our billing system household property figures also reconcile well with the local authority and ONS data for the base year.

We have used the local authority plan-based data as our primary projection of household properties in the WRMP as we have a higher degree of confidence in the accuracy of these plan-based figures.

Population Forecast

Figure 7-1 and **Table 7-2** show the annual population forecast until 2044/45. The trend-based and plan-based forecast are very similar, suggesting that local authorities mostly extract their population projections directly from ONS. It should be noted that there are more differences between the population trends than for the household trends; we have used the ONS dataset as our primary projection for our WRMP as these data carry a greater level of confidence. The local authority data are however used for sensitivity testing of the demand forecast. Overall, the total connected population in our supply area is forecast to rise from 1.21 million people in 2017/18 to 1.48 million people in 2044/45.

Figure 7-1: Bristol Water population forecast to 2044/45

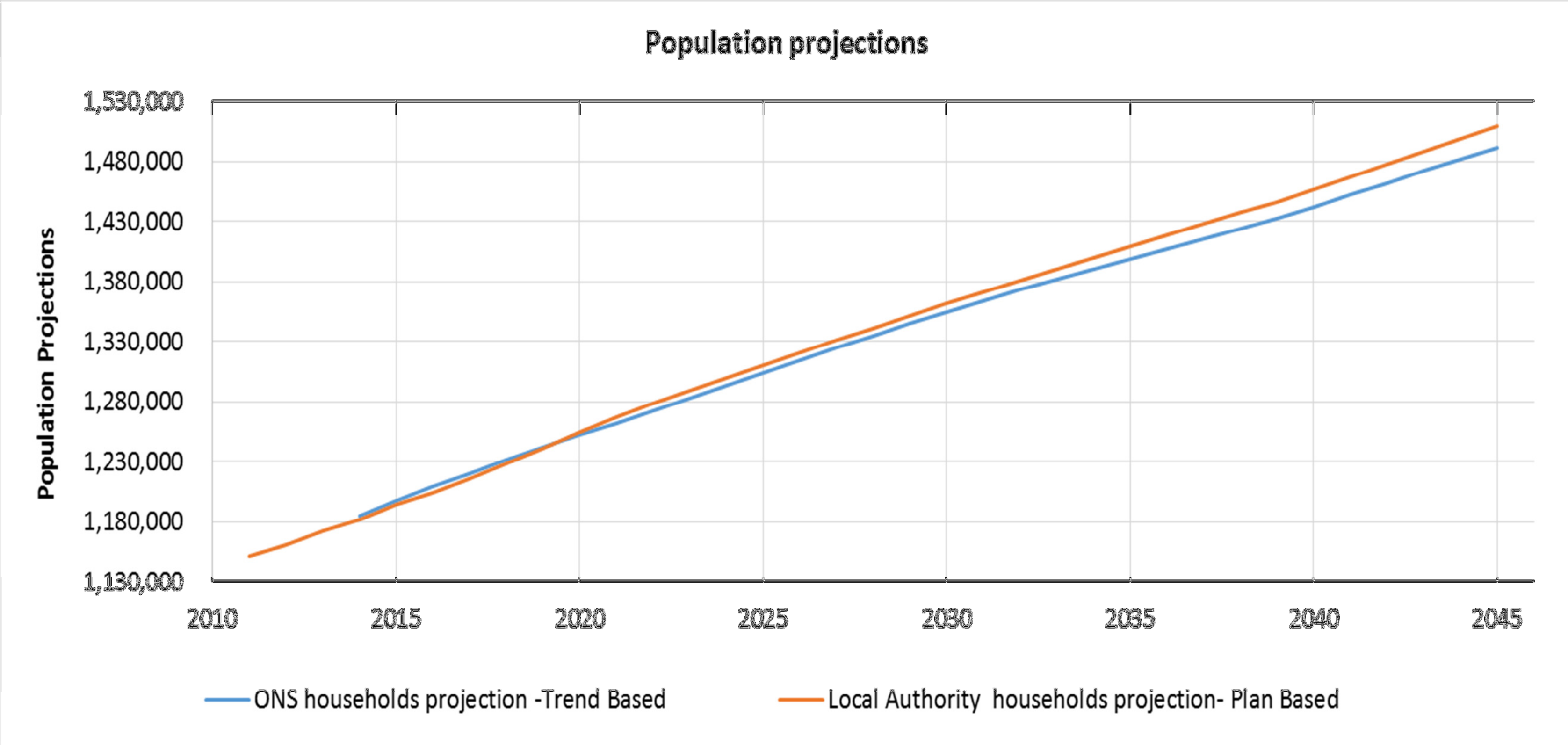


Table 7-1: Household property forecast

Household Property forecast	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/243	2024/25	2029/30	2034/35	2044/45	2017/18	2018/19
WRMP19 Trend-based	524,372	529,795	534,976	539,986	544,792	549,611	554,538	559,389	583,621	606,583	651,006	524,372	529,795
WRMP19 Plan- based	520,281	525,916	531,724	538,117	543,620	549,054	554,375	559,578	582,735	604,923	651,925	520,281	525,916
Current Billing System Data	489,955												

Table 7-2: Household population forecasts

Population projections	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24	2024/25	2029/30	2034/35	2044/45	2017/18	2018/19
WRMP19 Trend-based	1,231,185	1,241,801	1,252,227	1,262,364	1,272,746	1,283,217	1,293,549	1,304,070	1,354,453	1,398,951	1,491,738	1,231,185	1,241,801
WRMP19 Plan-based	1,228,093	1,241,057	1,254,411	1,267,242	1,278,320	1,289,316	1,299,920	1,310,441	1,361,589	1,409,473	1,509,726	1,228,093	1,241,057

Table 7-3: Occupancy forecast

Final projections from base year 2015/16	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24	2024/25	2029/30	2034/35	2044/45	2017/18	2018/19
Household Properties (Plan-based)	520,281	525,916	531,724	538,117	543,620	549,054	554,375	559,578	582,735	604,923	651,925	520,281	525,916
Occupancy (Trend-based)	2.35	2.34	2.34	2.34	2.34	2.33	2.33	2.33	2.32	2.31	2.29	2.35	2.34
Population (Household-plan*occupancy-trend)	1,221,580	1,232,707	1,244,615	1,257,993	1,270,007	1,281,917	1,293,169	1,304,510	1,352,396	1,395,123	1,493,842	1,221,580	1,232,707

Occupancy Forecast

In line with our use of the ONS trend-based data for the population projections, household average occupancy has been derived directly from the ONS household and population figures. The household occupancy data are then applied to the local authority plan-based household property numbers.

The trend-based occupancy data (weighted average for measured and unmeasured households), trend-based population data and plan-based household property data are shown in **Table 7-3**. These have been incorporated within the household consumption forecast model, and have been calibrated with the reported figures from our WRMP Annual Review 2018 (AR18).

7.4 Baseline Household Demand Forecast

7.4.1 Method selection

An assessment of suitable household consumption forecasting methods was carried out based on the 'Low level of concern' identified via our Problem Characterisation process (as described in **Section 5**). The assessment was carried out in accordance with the UKWIR (2016) guidance on the selection of appropriate household consumption forecasting methods, and application of these methods (*WRMP19 Methods – Household Consumption Forecasting 15/WR/02/09)*. This assessment indicated that micro-component forecasting was the preferred forecasting approach for the WRMP.

7.5 Micro-component Model development

7.5.1 Summary of approach

A new micro-component model was developed in two parts, firstly using observed relationships between certain micro-components and occupancy. This enabled base year and final planning year micro-components to be estimated, and therefore the rate of change of micro-component daily water use to be derived due to the change in occupancy over the planning period. Occupancy values for the base year and final year were determined for the property segments described in **Section 7.3**.

Secondly, trends in micro-components to account for technology, policy and behavioural factors were determined using a combination of historic micro-component data and future projections from the Market Transformation Programme. These two parts of the micro-component analysis were combined to form a total micro-component consumption forecast, as described in **Section 7.10**.

The household consumption forecast assumes Bristol Water will continue its current programme of water efficiency activities targeting behaviours, education and the uptake of water efficiency devices. These activities are assumed to suppress household consumption, maintaining it at a level that is lower than would occur without this activity. Section 8.3 provides further details of our baseline water efficiency activities.

7.5.2 Data availability

Bristol Water specific data

The base year selected for the WRMP is 2017/18. Base year figures were derived from the Bristol Water WRMP AR18 and associated regulatory reporting for 2017/18 for:

- Per capita consumption (PCC) for measured and unmeasured properties.
- Property, population and occupancy figures for measured and unmeasured properties.

A per household consumption (PHC) volume for measured and unmeasured households was then calculated from the reported PCC figures combined with the reported occupancy figures.

Additional data were used to either develop the forecast, or used for validation of the model, including:

- Our WRMP14 demand forecast and WRMP14 micro-component model.
- Base year property and population numbers from the company billing database.
- Measured household billed volume data.
- Historic reported data from the WRMP Annual Review/Ofwat annual performance reporting process, including distribution input.
- Historic weather data.

National datasets

In addition to our company specific data, several national datasets were used to increase the understanding of historic, present and future micro-component consumption. Historic micro-component data were extracted from the WRc CP187 report whilst current micro-component data were extracted from UKWIR (2016) *Integration of behavioural change into demand forecasting and water efficiency practices.*

Future projections were extracted from Defra's *Market Transformation Programme* (MTP) 2011. This work produced summaries for various water using appliances and provided predictions of water use for appliances and devices in 2030 for 3 different scenarios:

1. Reference scenario; equivalent to the baseline forecast;
2. Policy scenario; assuming more effective implementation and accelerated take-up of more sustainable products; and,

3. Early best practice (or EBP); which assumes a more positive impact than the policy scenario and an early take-up of innovative water efficient products.

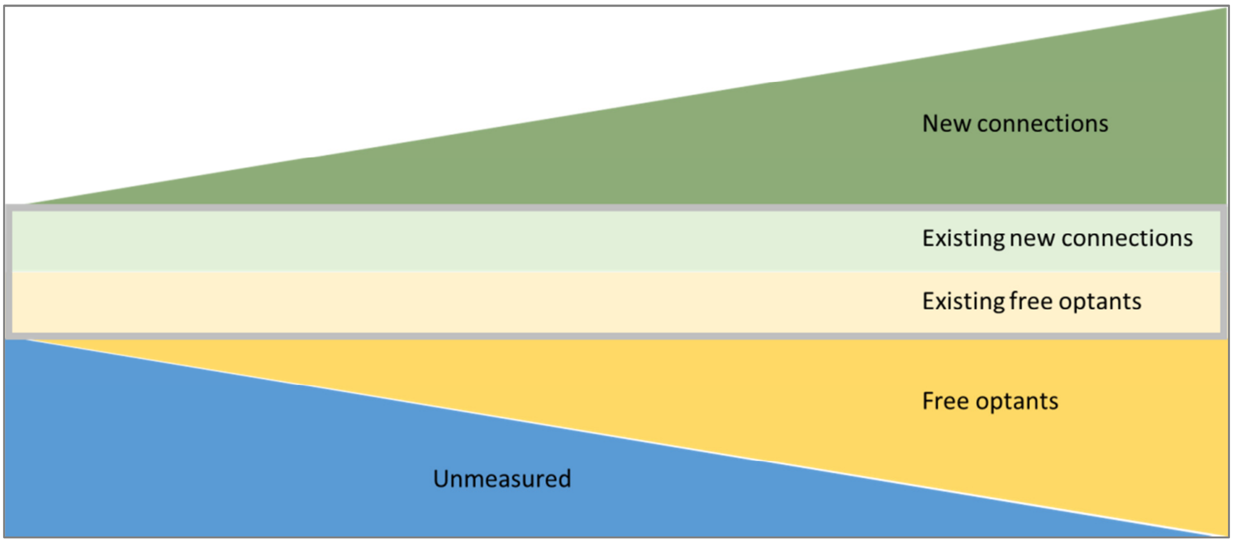
Property segmentation

Water companies are required to report consumption figures for measured and unmeasured properties. In order to fully understand the complexity of these different household segments and the differences in their consumption, behaviour and future trends, the measured household forecast was split into the following categories:

- Existing properties;
- New properties;
- Free meter optants; and
- Metering programmes (compulsory/selective/other).

Figure 7-2 provides an illustration of the breakdown of the measured and unmeasured households.

Figure 7-2: Illustration of the property breakdown within Bristol Water (forecast from base year to the point of 100% metering of households)



From the base year position, the number of new properties will increase based on the household property forecasts. The switch between unmeasured households to free meter optant households is based on the forecast optant rate: for the WRMP19, the optant forecast rate has been calculated using a combination of the WRMP14 forecast and the historic reported optant numbers. Included in the optants trend is our current change of occupier metering policy.

The assumptions made in the segmentation model include:

- New households will always be metered.

- Free meter optants move directly out of the unmeasured property segment.
- Void properties are forecast to remain constant throughout the forecast period, in that there are no further void properties added beyond the base year. Void properties were not included in the baseline forecast due to their negligible consumption.
- The point at which 100% household meter penetration occurs is based on the meter optant forecast.
- Despite 100% meter penetration being unlikely in practice, the year in which this point is reached is needed for mathematical calculation in order to balance the population figures. In practice, this point is beyond the forecast period.

Population must also be distributed into each of the property segments. The assumptions used to distribute population between the segments are:

- Measured households generally have lower occupancy than unmeasured households.
- New properties are assumed to have the company average occupancy rate – assuming that occupants are moving into new properties from a range of existing properties, measured and unmeasured, either within or from outside of the region, and hence are assumed to have a company average occupancy.
- Occupancy rates of new properties and optant properties are inter-dependent, in that the sum of the new and optant population within the existing measured households must equal the total for measured household population.
- Optants have a low occupancy; however this is dependent on the level of meter penetration (as meter penetration increases, occupancy for the unmeasured and optant properties increases until 100% meter penetration).
- The total population for the optant properties plus unmeasured remains the same throughout the forecast. This assumes that each year optants come from the unmeasured pool.
- The average occupancy rate from all the segments must follow the change in occupancy rate from the property and population forecasts.

These assumptions provided an estimate of the change in occupancy within the household segments over time. Each year of the planning period, the segments were calibrated to take into account the company level occupancy changes throughout the forecast period. There is a slight decrease in the company occupancy rate over the next 25 years, and this was distributed equally across all household segments.

7.5.3 Household consumption forecasts

Selection of the basic unit of consumption

Per household consumption (PHC) has been used as the basis for aggregating up to a zonal consumption forecast. A model based on PHC is property driven, which is consistent with data collection based on household meter readings. Occupancy-driven household consumption components are therefore implicit within the model.

In order to be able to meet the Environment Agency requirements that micro-components are reported in the WRMP in units of occupancy (i.e. per capita consumption), the model converts the PHC micro-component values at the zonal level to PCC by dividing by the occupancy rates.

Micro-component occupancy model

In calculating the base year and final year PHC values, a set of linear models were used to relate either daily use or frequency of use to occupancy in each year. The model was also used to provide the base and final year values for different metered property types (existing metered, optant metered, new property metered and selective metered).

The UKWIR 2015/16 micro-component data for measured billed households was used for the modelling because this dataset has a complete set of occupancy data for each household over the logging period. The total number of households in the sample was 62.

The following micro-components were assessed in terms of average daily use (or contribution to per household consumption):

- WC flushing
- Shower use
- Bath use
- Tap use
- Dish washer use
- Washing machine use
- Water softener use
- External use
- Miscellaneous use (including internal plumbing losses).

Each of the micro-components was investigated to determine whether the daily volume per use, frequency of use, or ownership varied significantly with occupancy. The following micro-components showed relationships where occupancy was a significant factor:

- WC flushing
- Shower use
- Bath use
- Tap use
- Washing machine use

A linear model was developed for each of these micro-components, where occupancy was the predictive factor. The model was used to calculate the micro-component daily use (and hence the per household consumption 'PHC') for the following property types based on the occupancy assigned to each property type in the base year and in the final year of the forecast.

- Unmeasured households
- Existing metered billed households
- Optant metered billed households
- New build metered households
- Selective (or compulsory) metered billed households

Application of the occupancy model in the base year is shown in **Table 7-4**. Occupancy, PHC derived from the micro-component occupancy model and the calculated PCC are shown. PHC and PCC (calibrated to the base year (normalised to NYAA)) are also shown in the table.

Table 7-4: ***Micro-component occupancy model parameters – Base year (adjusted to NYAA)***

Household (HH) types	Occupancy	PHC (modelled) l/prop/day	PCC (modelled) l/head/day	Base year (NYAA) calibrated PHC l/prop/day	Base year calibrated PCC l/head/day
Unmeasured HH	2.60	329.62	126.78	410.26	157.79
Existing metered billed HH	2.09	278.84	133.66	253.61	121.56
New build metered HH	2.33	273.48	117.41	247.63	106.31
Optant metered HH	1.71	225.21	131.97	204.27	119.70

Note: Data presented is model input parameters

Modelling PHC and PCC figures based on the final year occupancies are shown in **Table 7-5**. These figures do not apply the technology/behaviour/policy trends and therefore demonstrate the impact of the changing occupancy over time for each of the household segments.

Table 7-5: ***Micro-component occupancy model parameters – Final year (NYAA)***

Household (HH) types	Occupancy	PHC (OVF calculated) l/prop/day	PCC (OVF calculated) l/head/day
Unmeasured HH	2.78	342.18	123.24
Existing metered billed HH	2.08	278.36	133.77
New build metered HH	2.27	268.80	118.46
Optant metered HH	1.83	238.04	129.81

Note: Data presented is model input parameters

Using the base year and final year PHC values, a rate of change in PHC due to the occupancy change has been calculated for each household metered status.

Micro-component trend model – Baseline scenario

The trends in individual micro-components due to technology change, policies and regulation, and behaviour change were investigated and are discussed in the following sections. Data from the WRc micro-component report CP187 (2005) and from the UKWIR

2016 behavioural change study have been used to inform this assessment, as well as information from Defra's Market Transformation Programme (MTP).

WC Flushing

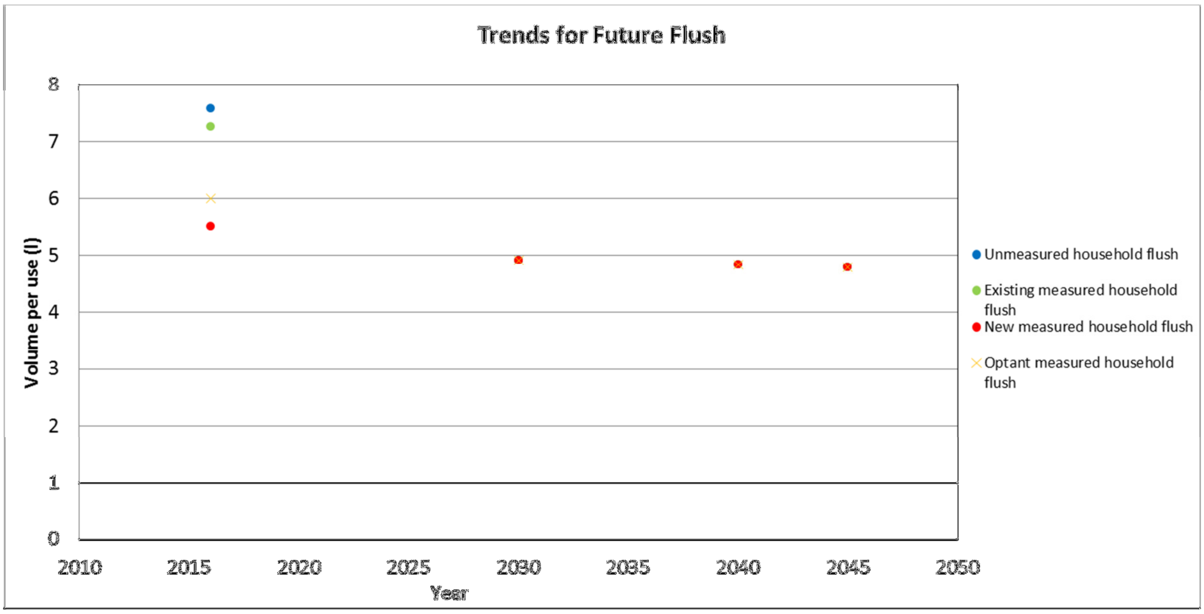
For the trend it was assumed that ownership and frequency of use for WC flushing remains constant, with the volume per use changing due to market transformation. Evidence shows that there has been a reduction in flush volume between 2002/04 to 2015/16 due to the replacement of larger volume WC cisterns with smaller volume cisterns, due to market transformation based on regulatory policies.

The future trends for WC volume per flush have been created using:

- The base year volumes per flush for different property types
- The 2030 projection for WC flush volume from the MTP report 'reference' scenario
- An assumption that WC flush volumes in all property types will have reduced to the MTP reference scenario between the forecast base year and 2030
- An assumption that the volume per use will then remain relatively constant until 2045

These trends are shown in **Figure 7-3** below. From these trends, annual rates of change have been produced for each of the property types. The rates of change have then been incorporated into the micro-component model.

Figure 7-3: ***Trends for WC flush volumes***



Showering, baths, washing machines and dishwashers

The same process was carried out to establish future trends of showers, baths, washing machines and dishwashers, with the findings shown in **Figures 7-4** to **7-7**.

Figure 7-4: ***Future trend for daily volume of water used for showering***

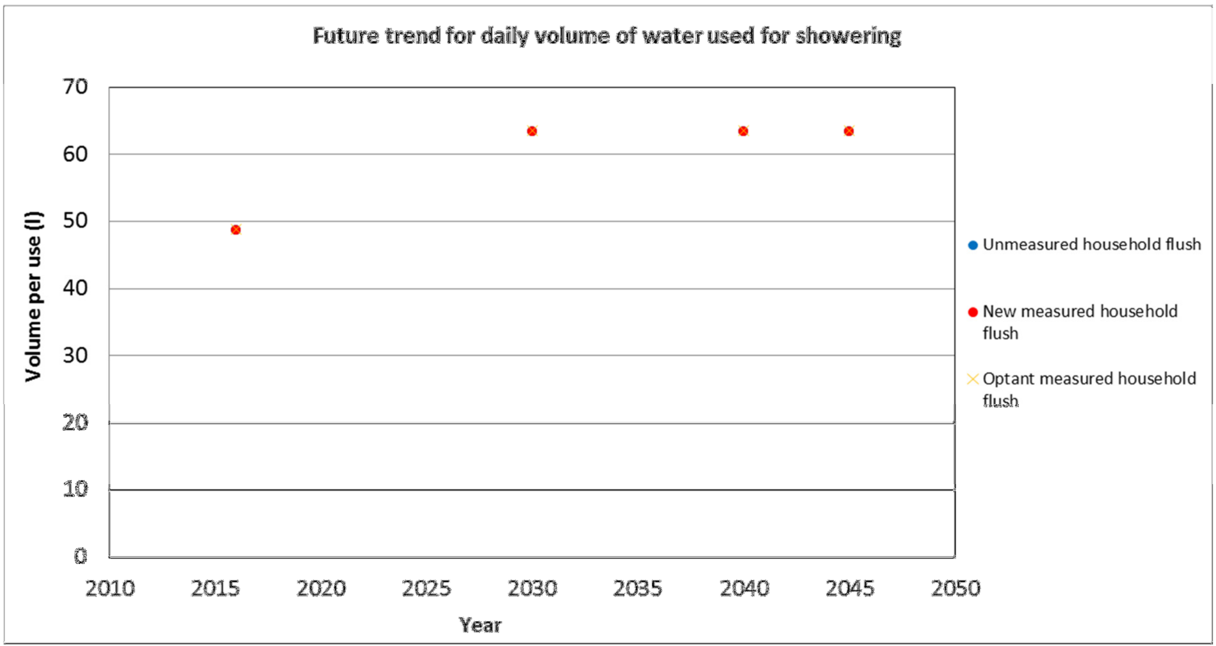


Figure 7-5: ***Predicted trends of daily volume of water used per household for bath use***

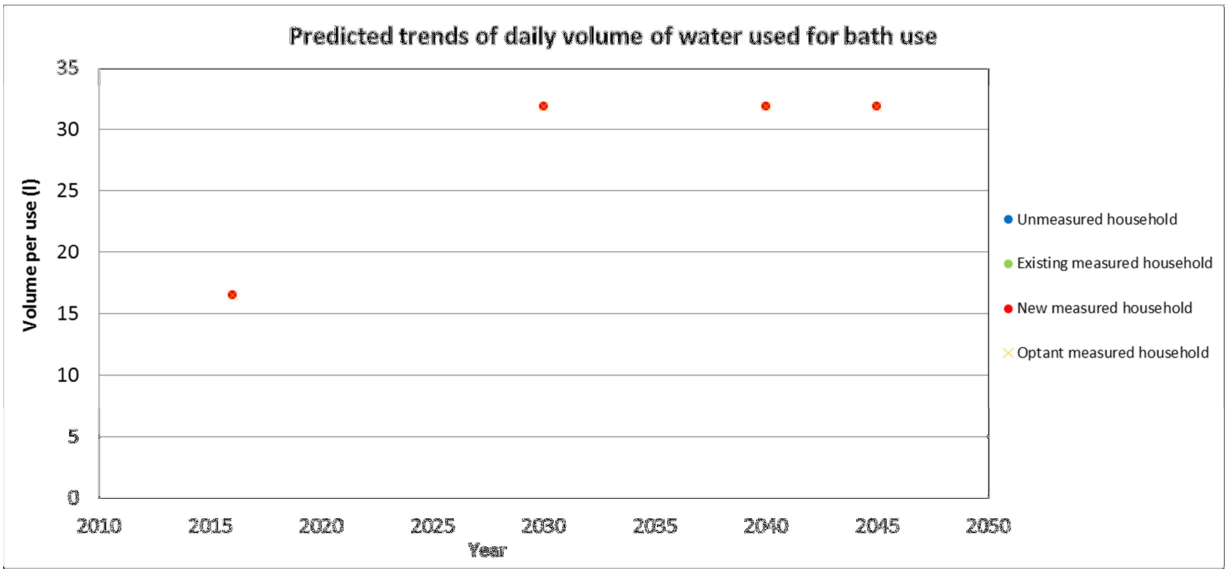


Figure 7-6: ***Future trend of washing machine volume per use***

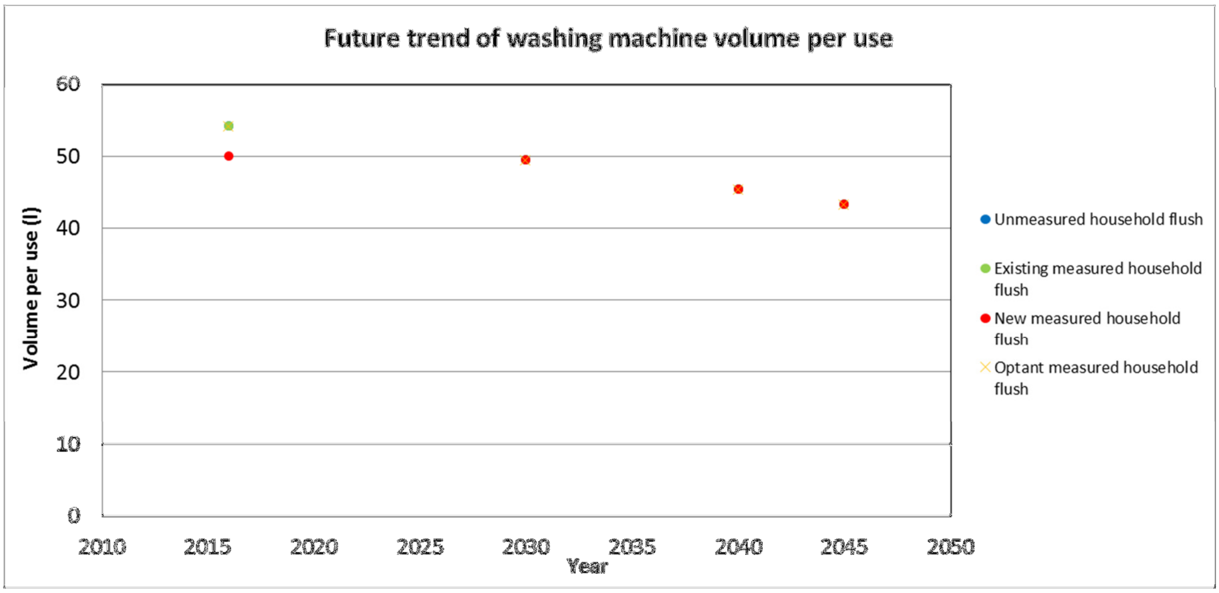
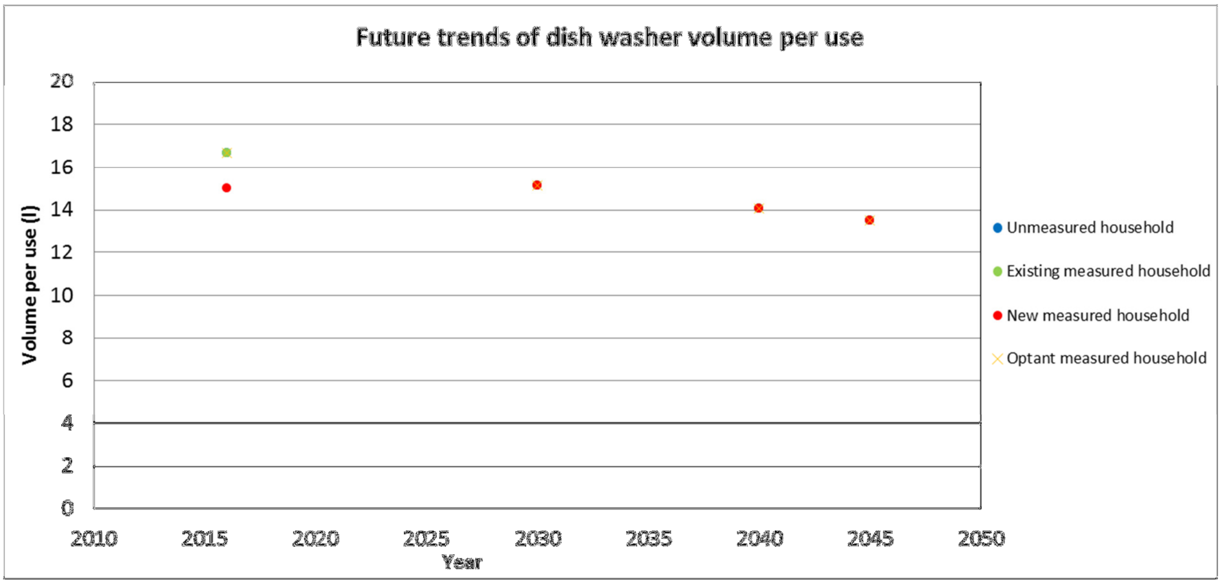


Figure 7-7: ***Future trends of dishwasher volume per use***



7.6 Base year calibration

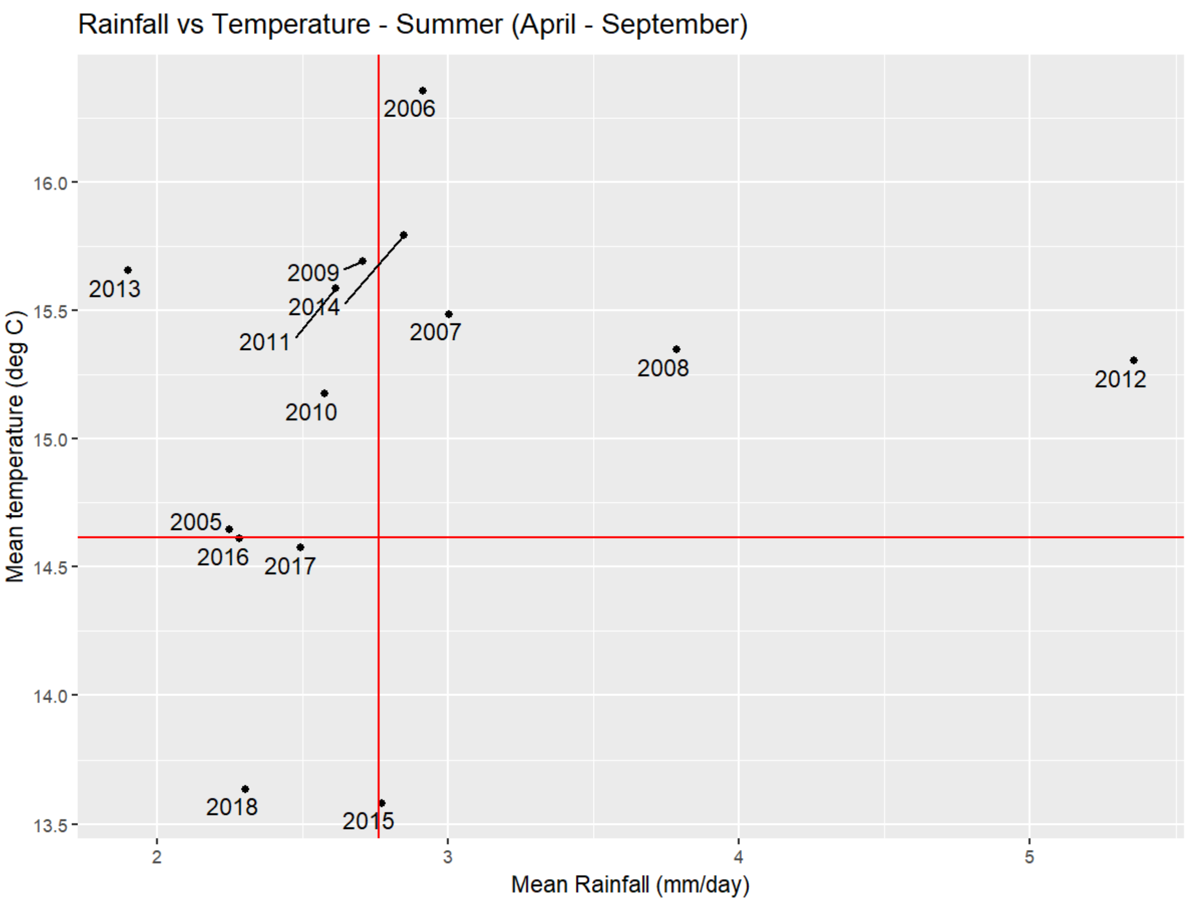
For each of the household segments, the OVF models were applied using the base year occupancy values. The OVF calculated PHC value was then calibrated to the normal year annual average (NYAA) value. The Normal Year factor is applied within the base year calibration to ensure that the rate of change over time for each component is not affected by annual variation that might be contained within the base year. The reported measured and unmeasured Base Year Annual Average values are then factored to the NYAA. The zonal PHC values for existing measured, new properties measured, optant measured and selective/compulsory measured are calculated proportionally based on the NYAA measured value using the OVF calculated PHC value in each segment.

7.7 Defining Dry Year Factor

The methodology set out in the UKWIR (2015) guidance '*WRMP19 Methods: Household Consumption Forecasting'* was used to derive the Dry Year Annual Average (DYAA) factor.

The rainfall and temperature data for the summer months were assessed. Total summer rainfall was assessed against mean summer temperature, with the mean temperature value of all years for the two factors plotted as red lines on the graph (**Figure 7-8**). A judgement is made as to which is the hottest and driest year: 2006/07 and 2013/14 are the most notable years in the top left of the quadrant which suggests a hot dry summer but 2011/12, 2009/10 and 2014/15 are also within the quadrant of hot and dry years.

Figure 7-8: *Quadrant plot for determining the dry year*



PCC trends for measured and unmeasured properties were then analysed. This analysis is carried out separately to account for the difference in trend and also the potential difference in impact of the dry year.

Based on the results, 2006/07 stands out as the year that is most significant out of the three possible dry years identified. In 2006/07, several companies enforced hosepipe bans, especially in the South East of England. We did not enforce a ban, however, media coverage of the ban may have led to some decrease in water consumption by our customers. Despite this, 2006/07 is the most appropriate year to use for the dry year factor.

The dry year factor is calculated by removing the dry year, then calculating a trend line through the remaining points. This method is suggested by the UKWIR guidance when annual consumption figures are the only ones available.

7.8 Accounting for the effect of climate change on demand

Climate change impacts on consumption have been calculated in accordance with UKWIR (2013) *Impact of Climate Change on water demand* report. Median percentage climate change impacts on household demand at 2040, relative to 2012, are published for each river basin within the UK. Bristol Water lies within the Severn and the South West England River Basins. A GIS analysis was conducted to derive the approximate proportion of the Bristol Water supply area within each river basin. This showed the coverage is 73.5% within the Severn basin and 26.5% within South West England basin. Taking account of the proportions of each contributing river basin, the annual average demand forecast was assessed as increasing by an average of 0.94% over the period to 2040 due to climate change (well within the expected range). However, as the base year is 2017/18 for the WRMP19 and the final forecast year is 2044/45, this percentage change was shifted along as there has been no further evidence produced since the 2013 UKWIR report and therefore the final percentage is slightly larger than the figure printed in the guidance.

7.9 Total household consumption forecast

Total company household consumption for DYAA increases from 169.26 Ml/d in 2017/18 to 184.25 Ml/d by 2044/45, which is an 8.85% increase in demand over the forecast period, as shown in **Figure 7-9**. Uncertainty in the household demand forecast is addressed in **Section 11** and incorporated within the target headroom allowance.

The increase in company level household demand is largely due to the increase in the number of properties throughout the forecast period. PHC and PCC decline slightly over the planning period which is largely based on the impact of increasing meter penetration. The PCC in the final year of the forecast is 129.43 litres/head/day, with a total company household consumption of 184.25 Ml/d.

Figure 7-9: Total household consumption (Ml/d), split by household segment

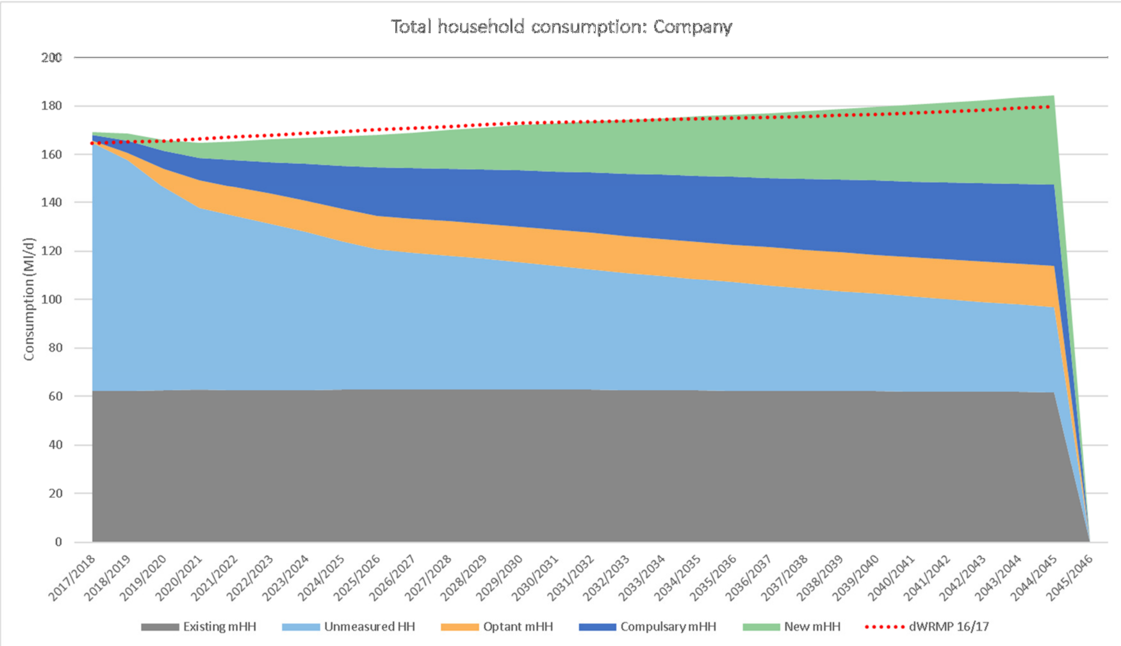
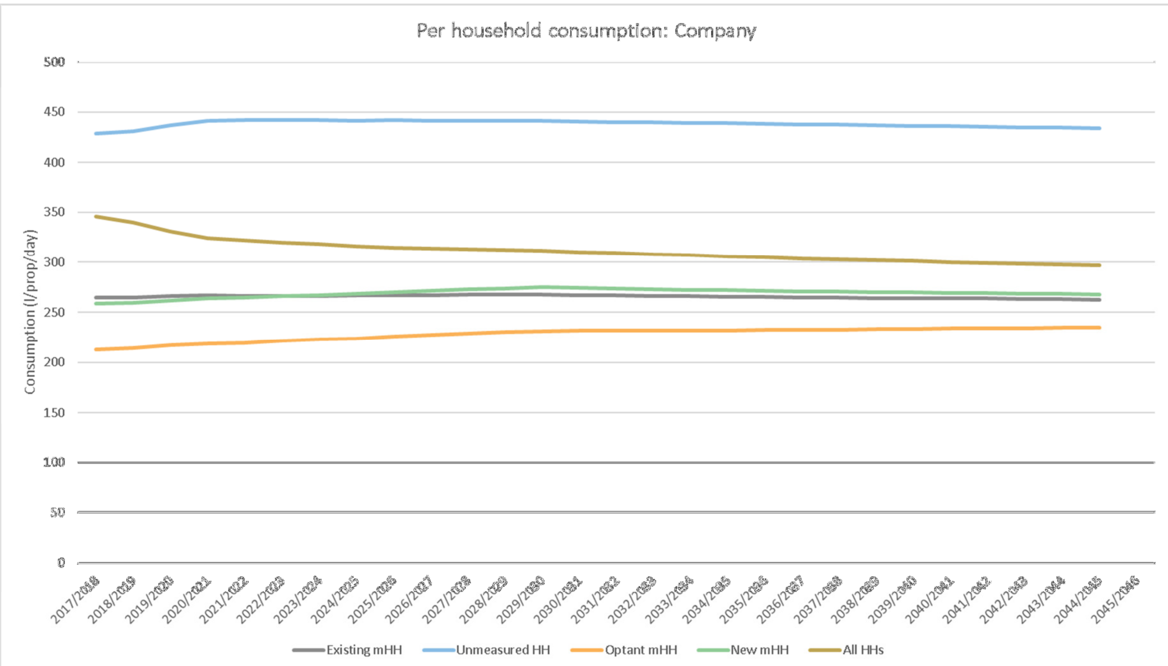


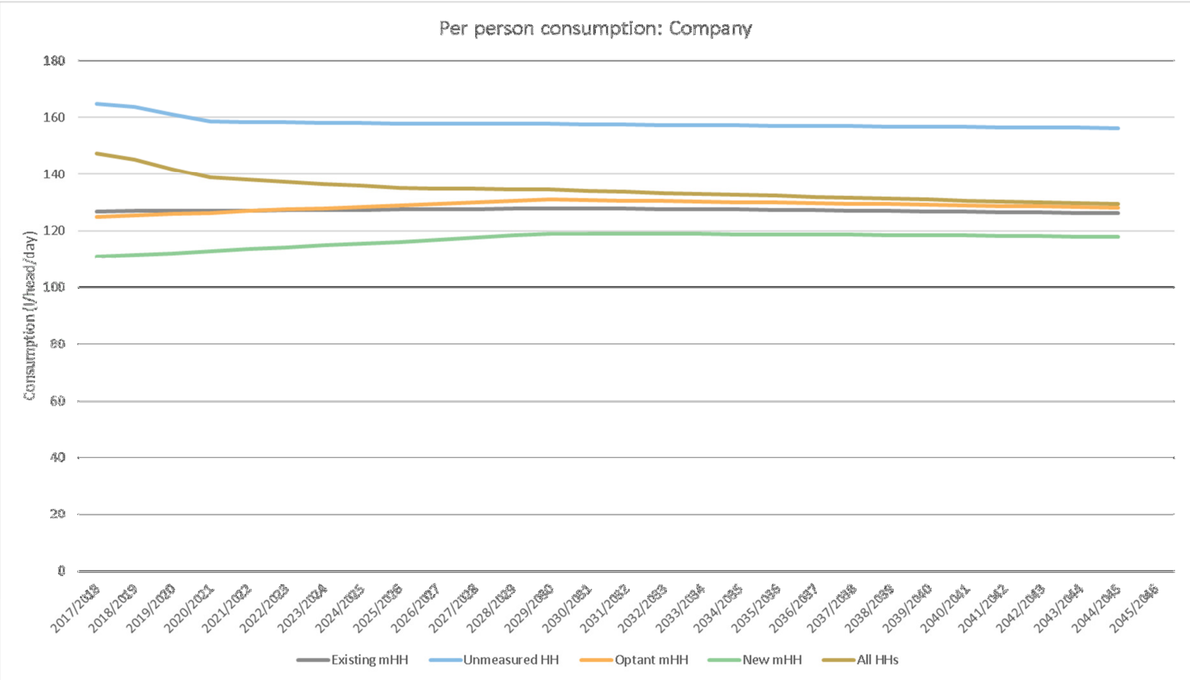
Figure 7-10 shows the PHC trend over the planning period, split by household segment. PHC decreases over the forecasting period from 345.47 l/property/day to just below 296.41 l/property/day. Each of the household segments have different trends, with the unmeasured households increasing from 428.29 l/prop/day to 433.76. Each of the measured segments remain quite stable, with a slight rise and then fall dependent on the rate of change developed from measured and MTP figures. The overall decrease in PHC is a function of the unmeasured households converting to optant properties with a lower PHC.

Figure 7-10: Company level PHC, split by household segment



Company level PCC (**Figure 7-11**) exhibits a similar trend to PHC, with a slight decrease from 147.34 l/head/day to 129.43 l/head/day. Unmeasured PCC shows a negative trend which is different to the PHC trend reflecting the small crease in occupancy rates within this segment. This is due to lower occupancy households converting to meter optants, while the higher occupancy properties remain in the unmeasured segment. The measured property segments exhibit a smaller decline in PCC as this segment becomes more predominant in our supply area with our continued metering activities and our actions to reduce PCC through targeted water efficiency measures. The unmeasured properties are characterised by a greater reduction in overall PCC due to the consumption by white goods and WC flushing being at a higher starting point.

Figure 7-11: Company level PCC, split by household segment



7.10 Non-Household Demand Forecast

7.10.1 Overview

Non-household demand[8] in recent years has recovered at a faster pace following the recession than predicted in our 2014 WRMP. The non-household demand trend during the recent economic recovery period has been assessed based on reported non-household total consumption and this confirmed an upward shift in non-household demand in recent years. Following a review of the available methods to forecasting future non-household demand, a trend-based approach was adopted as the most suitable method given the data available and the low risk problem characterisation of the Bristol Water WRMP.

[8]The non-household forecast is based on data from properties identified on Bristol Water systems as non-households, and includes a breakdown of property types as part of the forecast.

Recorded and reported non-household demand data were analysed to develop the demand forecast. The reported data were used to conduct a more in-depth analysis based on consumption bands. Trends by consumption bands were produced and compared. Recorded data were tested against a range of economic factors which included: population; Gross Domestic Product (GDP) from the ONS; and employment and unemployment rates. The analysis was conducted at both the aggregated non-household demand level and also modelled by 'division' segments, which identified a coarser classification of non-household demand according to the nature of the business activity. The analysis by the division segments showed little or no relationship with economic factors, while the aggregated demand model was statistically significant for the relationship to unemployment rates. The demand forecast does not include any assumptions on the levels of efficiency that will be achieved by current or future retailers, as there is insufficient evidence on this at present.

The trends identified from this analysis were calibrated to the non-household consumption in the Base Year and compared. This produced a range of likely scenarios with different trends in non-household consumption. In order to obtain the most likely scenario, the selected trends were combined to obtain a "mean" forecast. This was validated and a "median" trend produced which showed a similar behaviour to the mean forecast, confirming that the statistical distribution is likely to be a 'normal' distribution.

The reported consumption for the year 2017/18 falls well within the value forecast using the base year set at 2015/16, and the trends developed have been used and calibrated to the new base year of 2017/18 (60.48 Ml/d).

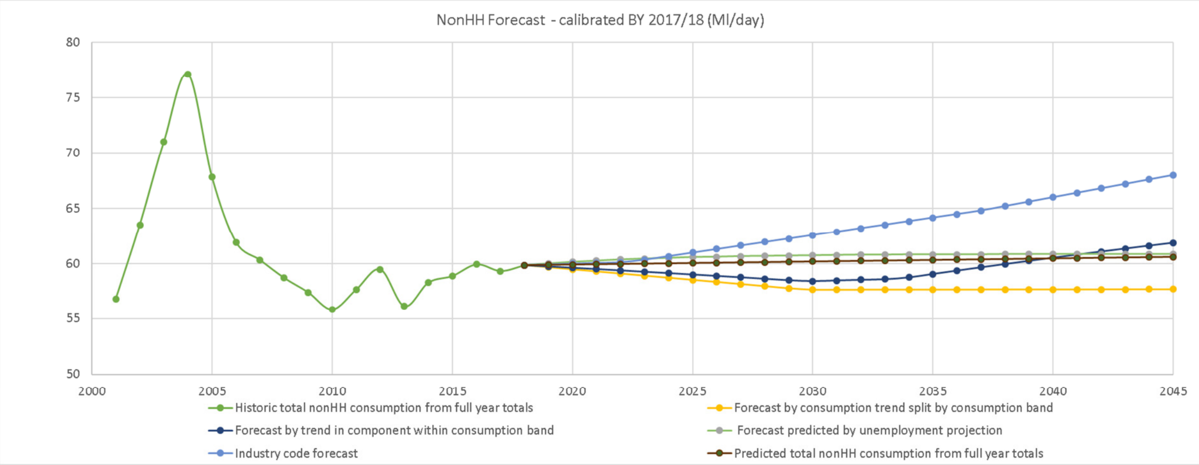
7.10.2 Non-household demand forecast

A set of non-household demand forecasts were developed for the 25-year planning period, as shown in **Figure 7-12**. The forecasts developed include:

- Predicted total non-household consumption from full year totals
- Forecast by unemployment projection
- Forecast by consumption trend split by consumption band
- Forecast by trend in component within consumption band
- Forecast by industry code

Figure 7-12 also shows for comparison the total historic non-household consumption from full year totals.

Figure 7-12: Non-household demand forecasts (Base Year 2017/18)



All the trends produced have been combined by using the average value for each year of the forecast to obtain the most likely scenario in non-household consumption. This mean forecast is shown in **Figure 7-13**. Uncertainty bands are drawn for the mean scenario with ± 97.5% prediction intervals.

Figure 7-13: Final mean non-household forecast (from Base Year 2017/18)

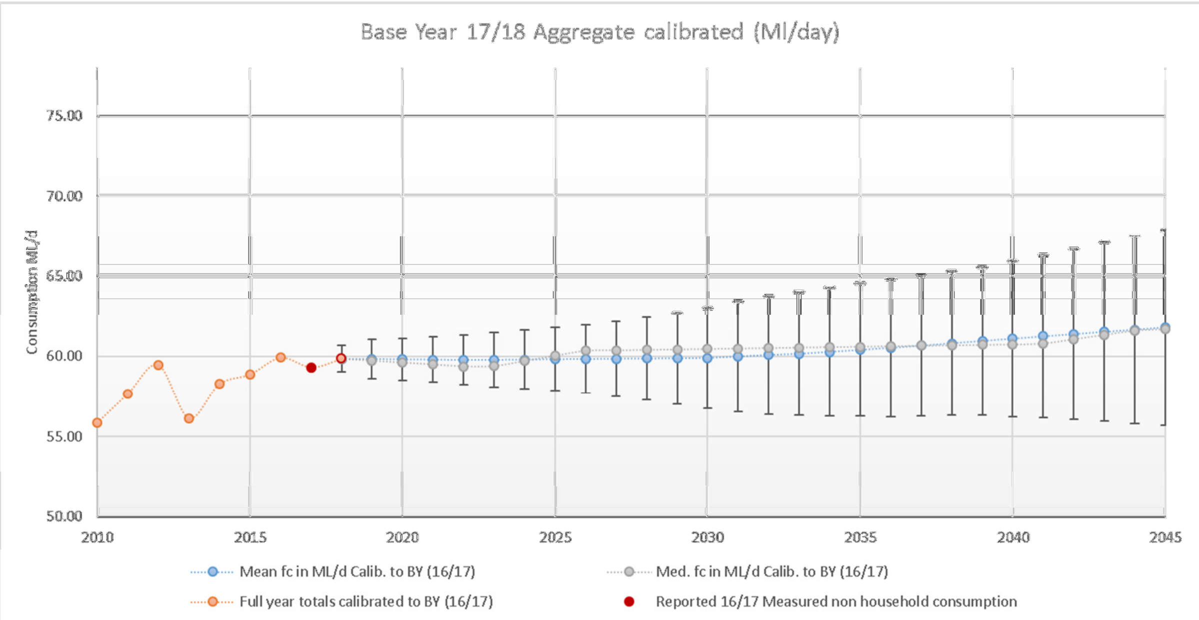


Table 7-6 details the forecast non-household consumption for each trend produced.

Table 7-6: Non-household consumption figures by each trend produced (Ml/d)

Forecasts	2019/20	2024/25	2029/30	2034/35	2039/40	2044/45
Predicted total non-household consumption from full year totals	59.9	60.0	60.2	60.3	60.5	60.6
Forecast by unemployment projection	60.1	60.6	60.7	60.8	60.8	60.8
Forecast by consumption trend split by consumption band	59.5	58.5	57.6	57.6	57.7	57.7
Forecast by trend in component within consumption band	59.6	59.0	58.4	59.1	60.5	61.9
Forecast by industry code	60.0	61.0	62.6	64.2	66.0	68.0
Mean forecast DYAA	**59.8**	**59.8**	**59.9**	**60.4**	**61.1**	**61.8**

7.11 Dry Year Annual Average Baseline Demand Forecast

Taking account of the above forecast changes in household and non-household consumption, along with our baseline leakage reduction profile (see **Section 8** for more details), baseline water efficiency policy (see **Section 8** for more details) along with our estimate of changes to water operational use and water taken unbilled (**Table 7-7**), we forecast that the total dry year annual average (DYAA) **baseline** demand (or DYAA Distribution Input) will rise gradually across the planning period from 281.40 Ml/d in 2017/18 to 290.11 Ml/d at 2044/45 (**Table 7-7**).

Base year operational water use and water taken unbilled was calculated based on a mix of operational records of licensed standpipe use plus estimates of water used for mains flushing and other operational activities, as reported in our WRMP14 Annual Review submission in June 2018. We forecast a small decrease to these components to 2018/19 and then assume a constant consumption thereafter for the baseline demand forecast (Table 7-7).

The base year demand components value and total distribution input were reviewed as part of our WRMP14 Annual Review June 2018 submission according to the water balance reconciliation approach.

The total leakage profile is divided between distribution losses from our water supply system and leakage from customer supply pipes. The measured and unmeasured demand forecasts include leakage from customer supply pipes except for supply pipe leakage arising from empty (void) properties (which is shown in **Table 7-8**). This shows that around 25% of total leakage occurs from customer supply pipes, with the remainder from our water distribution system.

Baseline supply pipe leakage from measured and unmeasured properties is forecast to reduce from a total of 11.71 Ml/d in 2017/18 to 9.87 Ml/d by 2044/45. **Table 7-8** shows the baseline total leakage profile which shows we are on track to deliver our leakage target for 2019/20 of 43.0 Ml/d. Our baseline leakage policy is to continue to reduce leakage to 39.33 Ml/d by 2024/25 and then maintain this level over the remainder of the planning period. However, this is not our final planning assumption for leakage as explained in **Sections 8** and **13**.

Figure 7-14: Components of our Total DYAA Demand Forecast

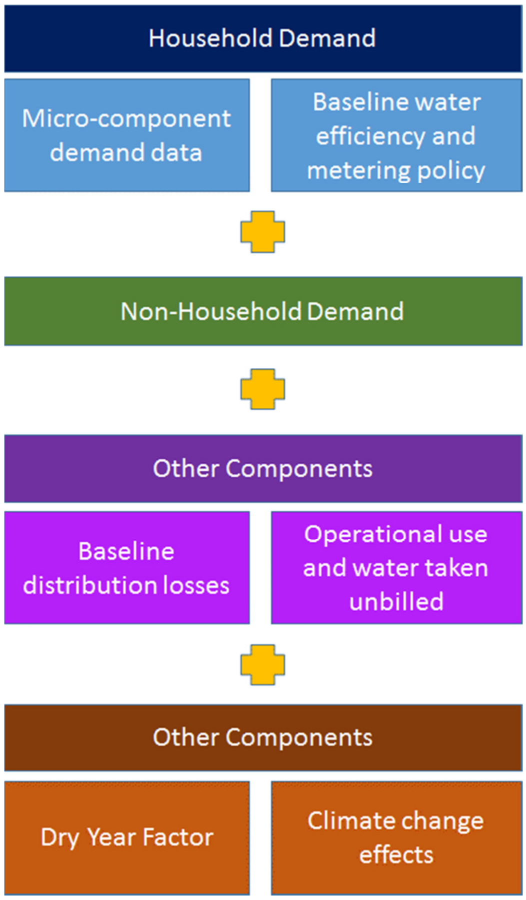


Table 7-7: Baseline Dry Year Annual Average (DYAA) Demand Forecast (Ml/d)

Demand Components	2017/18	2020/21	2024/25	2029/30	2034/35	2039/40	2044/45
Measured non-household	60.44	60.34	60.33	60.42	60.91	61.60	62.30
Unmeasured non- household	0.67	0.67	0.67	0.67	0.67	0.67	0.67
Measured household	71.54	94.10	110.04	123.64	133.68	143.37	153.18
Unmeasured household	108.49	80.24	66.53	57.57	50.99	45.21	40.14
Water taken unbilled	0.68	0.66	0.66	0.66	0.66	0.66	0.66
Operational water use	4.34	3.44	3.44	3.44	3.44	3.44	3.44
Supply pipe leakage from void properties*	0.30	0.27	0.26	0.26	0.26	0.26	0.26
Distribution losses	34.93	31.34	29.46	29.46	29.46	29.46	29.46
Total DYAA Dry Year Demand (Ml/d) (Distribution Input)#	**281.40**	**271.06**	**271.38**	**276.11**	**280.06**	**284.68**	**290.11**

***Note: customer supply pipe leakage from measured and unmeasured customers is included in the demand forecast values**
 # Note: Total Distribution Input value may not equal the sum of components at 2 decimal places due to rounding

Table 7-8: Baseline Dry Year Annual Average (DYAA) Total Leakage Profile (Ml/d)

Leakage Components	2017/18	2020/21	2024/25	2029/30	2034/35	2039/40	2044/45
Non-household supply pipe leakage	0.64	0.57	0.54	0.54	0.54	0.54	0.54
Household supply pipe leakage	10.76	9.66	9.08	9.08	9.08	9.08	9.08
Void properties supply pipe leakage	0.30	0.27	0.26	0.26	0.26	0.26	0.26
Distribution losses	34.93	31.34	29.46	29.46	29.46	29.46	29.46
Total Leakage (Ml/d)	**46.64**	**43.00**	**39.33**	**39.33**	**39.33**	**39.33**	**39.33**

8 Baseline metering, leakage control and water efficiency

Section Summary

Metering is widely regarded as the fairest way to pay for water, but customers have indicated very strongly to us that they do not wish to see full compulsory metering of all our household customers. Customers on a water meter have a lower use of water due to the increased understanding of water consumption and there is a demand management benefit as a result, but the cost-benefit of a significant increase in metering rates is not as high as other options for demand management. On this basis, we have not proposed in this plan a change from our existing policy of metering all new domestic properties; promoting voluntary take-up of water metering by unmetered household customers; and change-of-occupier metering for household properties. Nevertheless, active promotion and implementation of our existing metering policy is forecast to increase meter penetration rates from the current 51% (average in 2017/18) to 66% by the end of 2019/20 and progressively increased to 87% (average) by 2044/45.

Managing leakage is one of our most important responsibilities: Bristol Water has always met its leakage targets and our leakage rate is lower than the industry average. Our customers have however given clear feedback during our consultation process that they would like to see leakage driven lower, and willingness to pay for leakage reduction is high when compared with other options for water resource management. Our stakeholders and regulators have also given strong feedback that we should be more ambitious in our leakage targets. Government has endorsed this view and the National Infrastructure Commission has recommended that water companies need to go beyond current targets to help secure resilient water supplies in the future.

Water efficiency is mutually beneficial as our customers can save money on reduced consumption and our costs to supply can be reduced. Since we published our draft WRMP19, we have strengthened our commitment to reduce water consumption over the next 25 years and work towards our long-term aspiration of reducing average per capita consumption to 110 litres/person/day by 2050. We forecast that average per capita consumption will reduce from 141.6 to 129.4 litres/person/day between 2020 and 2045. This leaves a 15% gap to our 110 litre/head/day aspirational target for 2050. Closing this gap will require collaborative working with other water companies and local authorities as well as action by government over the coming years to:

- Influence customer consumption behaviour to become more water efficient
- Modify government policy to better support water efficiency actions, such as mandatory water labelling, more water efficiency standards for water using appliances and enhanced water efficiency requirements for new homes
- Incentivise manufacturers and innovators to reduce water consumption rates for household and commercial water using appliances.

A significant area of water efficiency, where reductions in demand can be made without compromising customers' lifestyles or livelihoods, is in helping people to change their water using behaviour. This remains a less well understood area of activity so we are working in partnership with the University of West England to research how to use new data and data analytics to improve our approaches, supporting our customers' objectives around sustainable, resilient and affordable services. We have already instigated the creation of the Resource West partnership with Bristol City Council, University of West of England (UWE) and other organisations to enhance the promotion of water efficiency in our supply area, and we will also work with neighbouring water companies through the West Country Water Resources group on water efficiency promotion.

8.1 Baseline Metering Policy and Demand Savings

Metering is widely regarded as the fairest way to pay for water. Customers on a metered tariff generally pay less than those on an unmetered tariff and have a financial incentive to make efficient use of water in their homes and businesses. Meter installation can, however be relatively expensive especially when not undertaken universally across a geographical area. There are also ongoing costs in relation to reading and maintaining the meters. Our current policy is to offer free meter installation for customers who request a meter and to install a meter upon change of occupancy of an unmeasured property.

We promote our free optional metering via our company website and, in addition, we are currently running a campaign called 'Beat the Bill'. The aim of this campaign is to demonstrate to customers that they could save money on their bill if a free meter is fitted. We are fitting meters at over 1,000 properties at Lockleaze and Filton and showing customers the difference between their normal bill and metered bill. If customers do not choose to switch to a metered bill, then the meter is in place ready for change of occupier meeting when the time comes.

The level of household meter penetration in our supply area is currently at 51% (2017/18 average) an increase of around 15% since 2010. With continuation of our baseline policy to promote free meter optants, meter all households on change of occupier and meter all new properties, our baseline demand forecast takes account of the metering policy demand savings for each metered customer segment (as explained earlier in **Section 7**).

Since publication of our dWRMP, consultation feedback and internal review we have revised our forecast principally reflecting the increased focus on our metering delivery in AMP6 to meet our 66% regulatory meter penetration target. We will need to continue this delivery focus in AMP7 (2020-25) and beyond to achieve the future targets in our plan. As a result of our baseline metering strategy, we now forecast an overall change to meter penetration in our supply area from an average of 51% at 2017/18 to 87% at 2044/45 (**Table 8-1**).

Table 8-1: Forecast meter penetration (% of total household properties) from continuation of our baseline metering policy (average values for year)

2017/18	2020/21	2024/25	2029/30	2034/35	2039/40	2044/45
51%	66%	74%	78%	81%	84%	87%

8.1.1 What our customers think about metering and cost-effectivenes considerations

Our customers have mixed views on metering. Our research suggests that some customers support metering in principle, but do not see it as a priority, while others oppose metering in general. This difference in views is also reflected in the responses from customers to our draft WRMP19 as reported in our Statement of Response. Overall, customers consistently place a low value on metering throughout all valuation research even though this is also viewed by these customers as the fairest way to pay for water. The triangulated willingness to pay data indicates that household customers value a 10% increase in metering at £0.6 per household/year (with a range of £0.4 to £1.8 per household/year). Non-households had a negative WTP for metering indicating they do not support metering, perhaps assuming that their bill would be higher as a result.

We do not have the power to impose compulsory metering but to investigate this principle we have undertaken additional customer research to explore and assess customer preferences and opinion on the principle of compulsory universal metering. The findings indicated that both households and non-household customers had a strong negative WTP for metering at -£8.89 and -£3.97 for household and non household a year respectively. Our customer research does not provide a compelling case for compulsory universal metering or installation of new metering measures such as smart metering on a large scale. We continue to see metering as an important part of our strategy to provide a resilient service, both in the short and long term, and in the absence of strong customer preference for any action other than our current policy, we have included in our baseline an assumption that we will continue the current policy of a gradual increase in water metering by promoting meter optants and installing metering on change of occupancy, both of which activities are included our reporting of meter optants. We explored a number of different scenarios for metering options in the future via the Options Appraisal (**Section 13**) but based on customer research and the responses to our draft WRMP19 consultation we consider that our baseline metering policy, allied to a strong water efficiency programme, remains appropriate for our forecast supply-demand position.

Cost-effectiveness considerations

As required by the 2017 Water Resources Management Direction 3(f), we have assessed the cost effectiveness of continuation of our metering policy and set this out in our PR19 Business Plan submission to Ofwat. Whilst the detailed cost information is commercially sensitive, a summary of the 5-yearly AMP installation and operational costs associated with maintaining our metering policy is provided in the table below.

	AMP7 2024/25	AMP8 2029/30	AMP9 2034/.35	AMP10 2039/40	AMP11 2044/45
Meter penetration	74%	78%	81%	84%	87%
Installation costs (£m)	11.86	4.99	3.78	3.44	3.21
Operational costs (£m)	2.034	2.144	2.226	2.309	2.391

Our assessment concluded that continuation of our metering policy provides the most cost-effective way to help customers reduce their water use when compared with the other options available for achieving customer demand reduction and represents a continuation of an approach that customers tell us is reasonable. As part of this assessement, we talked to 223 customers in a series of deliberative workshop events about securing adequate supplies of water in the Bristol area. During these events our customers told us that, over the long-term, they would prefer that we prioritise reducing demand before increasing supply as they see this as having a greater impact and cost. In a game that asked customers how they would like Bristol Water to prioritise various water resource measures we found that demand measures were chosen around twice as often as measures to increase supply. Leakage and water efficiency are the key mechanisms customers want us to use to reduce demand, but they also want us to make the most of our current water sources.

This focus on managing the supply-demand balance through demand reduction measures was supported by 85% of the 265 customers who responded to our WRMP consultation. The most common theme of these responses was that we should focus on reducing waste before building new infrastructure. We focused on the link between metering and leakage reduction in our second series of deliberative workshops held with 112 of our customers over the course of a whole day. Across the 112 customers, participants were evenly split when asked to prioritise water meters as a tool to reduce demand. We found that customers in our three highest income segments prioritised water meters more often, while those in the three lower income segments were more likely to say it was a low priority. When we asked our customers more about their views they confirmed that the potential for increased bills to those less able to manage them was the key concern for those opposed to meter rollout.

In light of these responses, we have decided to continue with our existing approach on metering as a fair, cost-effective and controllable way of receiving a bill for water. When we tested this approach in our WRMP consultation, 73% of 265 customer responses agreed that the plan strikes the right balance of risk for the short and long-term, with 21% of customers saying they didn’t know. When we tested our overall PR19 business plan with our customers, 93% approved of our proposals. When we asked whether customers were concerned that the plan might lead to unaffordable water bills 58% of customers said no, but again 18% of those who responded were unsure and 24% said they were concerned, most frequently mentioning the possibility of unforeseen work costs arising. On this basis we consider that our proposals are proportionate and provide a cost-effective and best-value approach for resilient supply to our customers.

8.2 Baseline Leakage Policy and Demand Savings

Managing leakage is one of our most important responsibilities and our leakage rate is lower than the industry average. Our customers have however given clear feedback during our customer consultation process and through responses to our consultation on the draft WRMP19 that they would like to see leakage levels driven lower, and their willingness to pay for leakage reduction is high when compared with other options for water resource management. This is echoed by our regulators and stakeholders, with clear feedback on our draft WRMP19 consultation that we need to be more ambitious with our leakage targets.

Total leakage is the sum of losses from our distribution mains, service reservoirs, trunk mains and from customer supply pipes. Our baseline total leakage policy assumed in the baseline dry year annual average demand forecast (presented above in **Section 7**) comprises the continuation of our active leakage detection and control activities, district metering and leakage data analysis to identify underground leaks, maintaining our pressure management activities, providing a free LeakLine number for the public to report leaks to us, and continuing to provide a free supply pipe leak repair service to our household customers to address customer supply-pipe leakage (see **Section 8.2.1** below). The baseline leakage policy also assumes the continuation of our water mains capital maintenance programme and asset renewal activities necessary that contribute to our work to manage the 'natural rate of rise' of leakage (associated with deterioration of the water mains network and customer supply pipes) so as to reduce total leakage to 43 Ml/d by 2019/20 and 39.3 Ml/d by 2024/25, and holding leakage stable at this lower level for the remainder of the planning period.

In recent years, focus has been placed on the importance of developing leakage targets that consider a wider range of environmental and social costs and benefits of leakage related activity, and not just the direct' financial costs and benefits. The target level of leakage is described as the 'sustainable economic level of leakage' (SELL), and this approach requires that companies consider – and include where possible in their leakage calculations - the full range of environmental, social and carbon-related costs and benefits associated with leakage and leakage control.

The demand savings achieved by our baseline policy align to our Sustainable Economic Level of Leakage (SELL) assumptions. **Table 7-8** in **Section 7** sets out the baseline leakage control savings to be achieved over the 25 year planning horizon **assuming no further changes to our leakage policy over this period**. These savings are included in the baseline dry year annual average demand forecast.

We have steadily reduced our total leakage over the last decade, regularly delivering leakage performance better than our sustainable economic level of leakage and meeting our own series of targets that we have derived from SELL. Our baseline total leakage forecast assumes we will continue to meet our target for total leakage and reduce leakage to our target of 43 Ml/d by 2019/20 as we set out in WRMP14, and that we will continue to reduce leakage to 39.3 Ml/d by 2024/25.

Following calculation of SELL, and in order to assess the potential sensitivity of SELL to a range of factors, we commissioned RPS Group to undertake a new assessment of the sustainable economic level of leakage (SELL) for assessment in the WRMP19 and for submission in our PR19 Business Plan. The additional SELL analysis provided an assessment of the sensitivity of SELL with respect to key components in the calculation, such as the marginal cost of water, background leakage, natural rates of rise in leakage and active leakage control costs. This assessment was used to provide a lower, central and upper range of SELL and these figures have been reported in our PR19 business plan tables following a full assurance process. From 2020 onwards, the central point of SELL is 39.3 Ml/day, the lower limit of SELL is 37.9 Ml/d and the upper limit is 40.7 Ml/day. As our targeted reduction of 15% brings leakage to a lower level than any of these figures, SELL does not have a direct impact on setting of leakage targets for our WRMP other than in the assessment of costs and the investment required to meet this leakage reduction has been fully included in our PR19 business plan and tested with customers. Our SELL report provides more details on the assumptions, costs and benefits that underpin the SELL profile (RPS, 2018) and is available on request.

It should be noted that water companies have been working together, co-ordinated by Water UK, to improve the consistency of reporting of total leakage performance, so that performance can be compared between companies more easily. This work is supported by Ofwat, the Environment Agency, Natural Resources Wales and the Consumer Council for Water. Since publishing our final WRMP14, updated leakage calculation guidance has been issued by UKWIR (2017). We have undertaken a full review of our leakage reporting methodology against the UKWIR guidance and have updated our leakage calculations to reflect this. We continue to work to improve some components of our calculation where we have identified some limitations in our historic methodology, in particular around our estimates of non-household night use and trunk main leakage. We have assessed the implications of the full application of the Leakage Consistency methodology. This will make very little difference to our calculated water balance components and leakage volumes as we were already largely aligned to the methodology. We plan to align fully to the new methodology over the next few years with full compliance in place by the 2020/21 reporting year at latest. The switch to the new methodology therefore makes no material differences to our demand forecast or baseline supply-demand deficit, nor does it change the demand management and leakage reduction programmes in this WRMP19.

8.2.1 Baseline leakage control strategy

We operate an active leakage control (ALC) strategy across the entire distribution network. The predominant leakage control method used is based on continuously monitored district metered areas (DMA). For this method, flow is monitored at DMA level. If such a DMA shows an unexpectedly high night flow then the area is temporarily divided into smaller districts and night flow at this level is monitored. This, together with leakage detection techniques such as sounding or use of leak noise correlators, helps to locate individual leaks and bursts.

Continuously monitored district metering and combined metering covers 98% of all properties. The remaining properties are covered by a policy of annual sounding. Pressure management schemes which reduce leakage use specialised pressure reducing valve installations cover 60% of all properties across our water distribution network.

Leakage at service reservoirs is monitored by means of a standard volumetric drop test performed on all service reservoirs as part of the routine structural inspection programme. This is based on a rolling cycle of inspections every 4 years. Additional tests are undertaken if unusual losses are detected.

All Trunk Mains are inspected for leakage through an annual programme of route tracing with sounding on valves and fittings. For sixty trunk main systems a water balance is calculated through logging of all inlets and outlets. The balance is used to highlight any large meter errors or inaccuracies within the balance. The balance is resolved to within +/- 5%, after which the balance is deemed stable. Forty-four of the sixty trunk main systems are now within tolerance, with the other sixteen being dealt with at present to improve metering accuracy.

These leakage control methods locate both Company and customer leakage. Leaks identified as being the responsibility of the Company to repair are carried out by a repair contractor within an agreed period of time. Domestic homeowners receive a free leakage detection and repair service for the first repair under the Leak-stop programme (second repairs are subsidised).

In **Section 13** we summarise the work we have been undertaking to update our Sustainable Economic Level of Leakage (SELL) assessment

In **Section 16** we set out our revised leakage reduction policy that reflects the strong feedback we received on our draft WRMP19 consultation that we need to set more ambitious leakage reduction targets that go beyond our SELL to take account of wider social and environmental drivers to reduce leakage. This Section therefore explains that we plan to reduce leakage by 15% by 2025 and reduce leakage further during the remainder of the planning period.

8.2.2 What our customers think about leakage

Leakage is a high priority for our customers with them being engaged in this topic. Leakage complaints accounted for 9.5% of all complaints in 2016/17 and leakage was the top reason of inbound customer calls, accounting for 25% of all operational inbound calls. Specific customer research has also indicated that leakage is high priority to customers and the results also indicated the customers would prefer us to consider demand management options before implementing new ‘’supply side’’ measures. These views have been reinforced in our customer research activity on the draft WRMP19 and comments received from customers as part of the consultation on the draft WRMP19.

8.3 Baseline Water Efficiency Policy and Demand Savings

We recognise we need to help our customers to value water and use it wisely. If customers can improve their water efficiency, this not only helps to reduce water demand (and therefore the impact on the environment), but can also help them to save money on their water bill.

Our household customers have indicated a strong preference for support on water efficiency and we understand that customers primarily look to us for advice and assistance to help achieve these savings. Our plan looks to meet these needs with sound, achievable ideas combined with useful and easy to install equipment whilst broadening our engagement strategy through an increased focus on education underpinned by further research and by developing a more strategic partnership approach with key stakeholders in the West of England.

We have strengthened our commitment to reduce water consumption over the next 25 years. This includes increased household metering allied to further water efficiency activities to work towards our long-term aspiration of reducing average per capita consumption to 110 litres/person/day by 2050. We plan to increase household metering from 66% of properties in 2020 to 87% by 2045. Together with additional water efficiency actions, we forecast that average per capita consumption will reduce from 141.6 to 129.4 litres/person/day between 2020 and 2045.

This leaves a 15% gap to our 110 litre/head/day aspirational target for 2050. Closing this gap will require collaborative working with other water companies and local authorities as well as action by government over the coming years to:

- Influence customer consumption behaviour to become more water efficient
- Modify government policy to better support water efficiency actions, such as mandatory water labelling, more water efficiency standards for water using appliances and enhanced water efficiency requirements for new homes
- Incentivise manufacturers and innovators to reduce water consumption rates for household and commercial water using appliances.

We have for many years worked to help our customers become more water efficient because it helps customers to save money (both in metered water bills and on energy bills) and also mitigates the environmental impact of the need to abstract water from the environment. Throughout the last few years (AMP6 period) we have provided water efficiency support and advice to our customers via our website; through engagement at public events; promotion through paper billing; and articles in other literature such as our customer magazine “WaterTalk”, which is issued to every household in the area we supply. Through this range of approaches, our customers are provided with information on how to access free water saving devices for use within the home, obtain bespoke information on the financial savings that can be made by being more water efficient, and get access to subsidised water-saving garden equipment such as water butts and hand-pumped pressure washers.

Our baseline water efficiency policy and activities set out in section 8.3.2 will build and improve on this on work, striving to meet our customers’ needs and expectations for both for metered and unmetered customers whilst offering the advice, education and means to help them lower their water usage without diminishing the overall value of the water service and utility they receive.

8.3.1 What our customers think about water efficiency activity

Our customer engagement programme throughout the development of our WRMP has indicated that household customers have a strong preference for support on water efficiency, demonstrated by willingness to pay and customer priorities. 92% of online customer research panel members told us that “improving water efficiency to reduce demand and help meet future needs of a growing population” is important. Most customers responding to our draft WRMP19 consultation agreed that improved water efficiency and more education on water efficiency were important parts of balancing future demand and supply. Some customers commented that metering should make use of modern technology, for example through installing ‘smart’ meters linked to the provision of Apps to help customers monitor their water consumption. Our deliberative engagement workshops with a representative sample of customers held during the consultation period on our draft WRMP19 further reinforced these views.

Although our investigation of the costs and benefits of water efficiency (**Section 13**) indicates that the savings achieved immediately may not be very high and the marginal cost of improvements can be higher than other options available to balance supply and demand, due to the strong customer preference for work in this area we will therefore continue to plan to enhance our water efficiency support work as part of our baseline policy as detailed below in Section 8.3.2.

We accept that there are varying views on how we should approach water efficiency. For example, increasing the use of water efficiency devices was identified during our WRMP consultation process as a priority by some customer groups - while others felt we should prioritise investment in education and the installation of water meters first, as they believed this would encourage people to buy their own water saving devices.

There is limited specific quantitative information available on the effectiveness of messaging and education around water efficiency in our supply area, particularly in time of drought conditions where water conservation messaging and public awareness can have a helpful effect on reducing peak demand for water. Because of this uncertainty, we have not assigned any specific volumetric saving to our baseline water efficiency activity in addition to our demand projections across the planning period to 2045. However, as explained in **Section 7**, our micro-components forecasts include for the water efficiency trends expected in relation to household water use.

In order to begin addressing this uncertainty and to support water efficiency measures across the UK water industry, we have entered into a research partnership programme with the University of the West of England, using consumption data from smart metering installed throughout the University's student accommodation portfolio - with subsequent information and communication trials to investigate the impact of messaging around water efficiency. This research programme provides the largest test-bed of its kind in Europe and will continue to develop and inform the approach we take in the future on water efficiency messaging and the impact of physical water efficiency interventions.

8.3.2 Our baseline water efficiency policy and activities

Our performance commitment: For AMP7, per capita consumption will be a common performance commitment for the water industry with financial penalties and rewards. Our performance commitment will be 135 l/h/d by 2024/25 (annual average consumption for the reporting year). This is aligned to our WRMP19 forecast that dry year average PCC will reduce to 135.8 l/h/d by 2024/25 and will further reduce to 129.4 l/h/d by 2044/45.

Our water efficiency programme will help to achieve this target and will focus on eight key areas:

- Continue promotion of water metering with provision of targeted water efficiency advice
- Continue provision of free water efficiency equipment
- Continue provision of bespoke water efficiency calculations (through our website) to empower customers to choose the most effective way to save water and save money
- Develop new partnerships with stakeholders across our supply area to create new and innovative ways to help customers become more resource efficient
- Develop our evidence base and research programme on the most effective water efficiency measures
- Continue and increase our schools education programme on water efficiency and its links to environmental sustainability
- Work within the industry to share expertise and knowledge and lead development of initiatives like the water label to help customers understand water usage when buying equipment
- Work with retailers to help them help their non-household customers use water efficiently.

Further details on each of these areas are set out below.

Continue promotion of water metering with provision of targeted water efficiency advice: We consider that metering is a highly effective way to drive reductions on PCC and with our metering programme for AMP 7 planned to achieve an overall metering penetration of 75% by the end of 2024/25, we anticipate the impact of this work to drive down PCC to help achieve the overall PCC performance commitment. We know that a significant impact of metering for many customers is to focus the mind on overall usage and its direct relation to cost. In this regard offering water efficiency advice, information and equipment is an important component in our offer to customers who are considering having a meter or who have one installed and are actively looking to become more efficient. This help and advice has far wider benefits and pertinence than simply lowering water usage within a household. We know that using a more water efficient shower head or only doing a wash when there is a full load will help reduce energy costs though cutting down the amount of water that needs to be heated. Customers are increasingly aware of the relationship between water usage and energy costs, due in part, to the increased access to high frequency energy usage data through smart energy meters which allows them to monitor where there power usages costs lie. We realise that customers are more likely to act in a more water efficient way if we help them understand all of the inherent benefits of water efficient behaviours and we will therefore highlight the energy link as an additional and compelling reason to use water wisely.

Continue provision of free water efficiency equipment: The provision of a range of free water saving devices that are easy to use or install has been a staple offering for the last 10 years. This equipment can be used in the bathroom, kitchen and garden with each one capable of saving measurable amounts of water. We will continue to offer a wide range of devices and help and we will be open to and looking for new ideas and equipment as they come to the market.

Continue provision of bespoke water efficiency calculations (through our website) to empower customers to choose the most effective way to save water and save money: Whilst water plays an important part in all our customers' lives we know for many there is quite a low level of understanding when it comes to quantifying total water usage. From brushing teeth to flushing a toilet, the daily and frequent activities we all do are somewhat mundane and forgettable. At the most basic level, understanding just how all of these individual acts add up and what difference a change of habit or the installation of a piece of equipment might have is a crucial first step in appreciating the benefits that water efficiency presents.

To help engage customers on learning about their habits and usage, we offer an online water and energy calculator service that allows users to fully engage on all aspects of their water usage as well as key aspects of how this usage is linked to energy consumption. Our current platform allows us to offer free water saving equipment following a user's interaction, at a time when the relevance and use of these items becomes more pertinent. We believe that the continuing development of a water and energy usage calculator, linked to the growing level of digital interactions we plan to offer, will allow us to better communicate water usage details that will encourage greater engagement. We believe this will lead to a better understanding of usage and a subsequent desire to consider offers or take actions that can help.

Develop new partnerships with stakeholders across our supply area to create new and innovative ways to help customers become more resource efficient:
We believe Bristol Water's unique role at the heart of the local community combined with the region’s strong sense of identity places us in a position to develop and build partnerships with a range of organisations such as local government, the Local Enterprise Partnership, housing developers, other water companies and academic institutions. Underpinning this belief is the recognition of the importance of communicating a joined-up message to customers on water efficiency activity, which links resource efficiency with saving money and environmental benefits. Given the close geographic match between the Bristol Water supply area and the West of England economic area, we have also been able to work closely with the West of England Combined Authority (WECA) to begin exploring opportunities to promote the principles of environmentally sustainable economic growth.

The work on developing this initiative beyond the concept stage has already begun with Bristol Waste, Bristol Energy, the University of the West of England and the West of England Combined Authority and Wessex Water joining us in the formation of a more formal partnership and the subsequent creation of our umbrella organisation ‘Resource West’ following a workshop with interested members facilitated by and held at the Knowle West Media Centre. This new organisation will aim to help create resilient communities and businesses by bringing together organisations already working on water, waste and energy efficiency, finding the synergies between key issues to increase the opportunity for overall resource efficiency and develop the West of England as a national hub for green growth.

The next phase of this project will explore special projects that can be shared between this range of organisations, looking to create regional “flagships” to spotlight the West of England area as a leader in green growth, innovation and sustainability. In particular we will look at exemplar projects in both new and existing housing and business developments to demonstrate how resource-efficient developments can be economically beneficial, improve social and economic resilience and address key issues around inequality and cost of living.

Develop our evidence base and research programme on the most effective water efficiency measure: We accept that there are varying views on how we should approach water efficiency. For example, increasing the use of water efficiency devices was identified during our WRMP consultation process as a priority by some customer groups - while others felt we should prioritise investment in education and the installation of water meters first, as they believed this would encourage people to buy their own water saving devices.

There is limited specific quantitative information available on the effectiveness of messaging and education around water efficiency in our supply area, particularly in time of drought conditions where water conservation messaging and public awareness can have a helpful effect on reducing peak demand for water.

In order to begin addressing this uncertainty and to support water efficiency measures across the UK water industry, we have entered into a research partnership programme with the University of the West of England, using consumption data from smart metering installed throughout the University's student accommodation portfolio - with subsequent information and communication trials to investigate the impact of messaging around water efficiency. This research programme provides the largest test-bed of its kind in Europe and will continue to develop and inform the approach we take in the future on water efficiency messaging and the impact of physical water efficiency interventions.

In 2018 we became part of an exciting new three year joint research project entitled SUNEX. This project falls under a global initiative called Sustainable Urbanisation Global Initiative which looks at the Food-Water-Energy Nexus. SUNEX in one of 15 projects talking place globally with an overarching aim of brining together research and expertise across the globe to find innovative new solutions to the Food-Water- Energy Nexus challenge.

SUNEX will provide a modelling framework to assess the Food-Water-Energy system. Bristol Water is being funded externally for this work where we will lead on the water aspect of the project and working with The University of the West of England will build the core model which will be water demand based. The overall objective is to develop efficient solutions for energy, water and food supply for urban regions and joining us in the project to develop the food and energy aspects of the overall model are the cities of Berlin, Vienna and Doha.

By working in partnership with these other cities, and by sharing, knowledge, experience and expertise between all the members we hope to gain valuable insights and develop a better understanding of ways to develop more efficient aspects of our water supply and demand management. One example of an area we intend to include within our modelling are the 120 or so allotments that are located within the city of Bristol.

Continue and increase our schools education programme on water efficiency and its links to environmental sustainability: On its own, providing water efficiency advice about how to save water is just one aspect of the much larger picture about how we all use water and the impact this has on us and the environment. Saving water is not just about lowering a bill if you are on a meter; it is about a deeper appreciation of the value of water in our environment and how important it is to our daily lives. In this regard, we believe, as the local water supplier, it is our duty to ensure we frame any water efficiency advice within the context of these wider environmental and health perspectives. Our plans above for leading the development of a Resilient and Efficient West of England are in this vein as has been our work on maintaining the visibility and understanding of the importance of water supply and good healthy hydration though our award-winning project, “The Water Bar”, which provides drinking water access at festivals and other events.

We see the core for this ideal residing within the world of education. Young, inquisitive minds eager to learn in a school environment that is teaching them from a wider environmental and sociological perspective where we have an opportunity to engage, challenge and influence.

Our award winning AMP 6 programmes “Trout and About” and “Spawn to be Wild” were examples of this, targeting primary schools in socially deprived areas, emphasise the link between the efficient use of water and the environment. For our AMP 7 plans will build on this work as well as developing a more comprehensive education offering based on increasing interaction and building a wide-ranging digital resource base that offers teachers more tools and engages with students at all stages of the curriculum.

Work within the industry to share expertise and knowledge and lead development of initiatives like the water label to help customers understand water usage when buying equipment: Every company within the water industry is trying to help customers with water efficiency. Much of the overall work is by the nature of its intent and targeting quite similar and many actions are mirrored across companies. But, there are also significant examples of variations in tactics, messaging and actions as well as variances in research to be found in all supply areas. We are keen to learn from others and share our insights where we can help. As an industry, water efficiency is perhaps one of the best examples of how this more collegiate approach can offer new opportunities and insights we as individual companies might miss. Whilst our unquestioned priority will always be our customers, in many circumstances sharing our collective knowledge and understanding is not only likely to help all of us achieve better results that benefit our customers, but good ideas that are shared will have an overall knock-on beneficial effect for the environment in general.

We will seek to ensure we are a strong voice within the industry to lead by example where we have new ideas, to be receptive to insights where others are finding success and to share compatible ideas where the sum of collective endeavour might outweigh single intent.

Work with retailers to help them help their non-household customers use water efficiently: Our water efficiency programme is primarily focused on household customers following the advent of non-household retail competition in April 2017. This activity has now become one of the main areas of focus for the new non-household water retailers and has therefore ceased to be the direct responsibility of water wholesalers such as Bristol Water. It is early days in the development of the retail market and consequently our focus has been on building up a good relationship with the new retailers. However, we want to help encourage water efficient practices to all users of the water we supply and we are eager to support all the retailers in their efforts to help their customers save water.

We have a good working relationship with each retailer in the market and provide support and information both in response to their requests and through ideas generated internally where we feel we can relay useful help and advice. A good example of this was a water efficiency poster campaign we designed and produced that allowed them to brand and use as they felt necessary for their customers. We also provide general water efficiency advice via our web site and retailer portal which we will continue to develop.

9 Sustainable Abstraction

Section Summary

We have to consider the sustainability of our water abstractions from the environment, as water resource availability can be affected by reductions in our licenced abstraction required by the Environment Agency, in order to support and restore the wider water environment. Currently we have no licences which need to be reduced, and our WRMP19 reflects this situation.

Nonetheless we have been advised by the Environment Agency that 10 of our locations require further investigation under the Water Industry National Environmental Programme (WINEP), as confirmed in the third version of the WINEP issued in spring 2018 (WINEP3). In future WRMPs we may therefore have to reduce our take from these locations but currently our expectation is that the impact will not be large at less than 6Ml/d.

We have also been advised by the Environment Agency to review the risk of transferring damaging invasive species through imports of raw water into our system. We will be undertaking an assessment in accordance with WINEP but we expect to be able to manage any such risk.

9.1 Overview

The following section details the work undertaken by us and wider stakeholders to mitigate any effects of our operations on the environment. We will continue to work with regulators and stakeholders to deliver environmental enhancements, our WINEP3 commitments and to meet WFD and RBMP objectives for rivers, lakes and rhynes.

9.2 Existing Sustainability Reductions

Bristol Water does not operate any abstractions which have been identified by the Environment Agency through the RSA (Restoration of Sustainable Abstraction) mechanism as unsustainable, although as stated in **Section 6.3.1** the company has for many years worked in partnership with Wessex Water to mitigate the impact of unsustainable abstraction by Wessex Water in the Malmesbury area, close to Bristol Water's area of supply. As part of this scheme, Bristol Water has voluntarily reduced the amount of water abstracted from its sources at P25Rand P33R, so that water can be abstracted from this aquifer by Wessex for local river support. This river support programme and voluntary reduction in abstraction by Bristol Water helps reduce the negative impact of Wessex Waters abstraction from groundwater in the area.

9.3 Current projects

9.3.1 Water Framework Directive Hydroecology Investigations

Under the Environment Agency's current National Environment Programme (NEP), Bristol Water has been investigating how downstream river ecology is affected by P42R and P39R Reservoirs. Reservoirs by their nature impound water and can therefore directly affect downstream river flows, in terms of flow magnitude, timing and rate of flow changes, seasonality of flows and flow variability. Reservoirs can also affect downstream water quality, temperature, sediments, and the movement of migratory fish such as eels.

We have firstly assessed the extent the reservoirs do cause impacts and are in the process of implementing options trials to understand what we can do to reduce or mitigate impacts. This work is being undertaken in consultation with the Environment Agency.

9.3.2 P41R Yeo Water Quality Investigation

We have collaborated in an investigation into the influences on water quality in the P41R Yeo downstream of P42R Reservoir. This work was co-funded by Bristol Water, Wessex Water, the Environment Agency and Yeo Valley Farms, and the aim was to understand the relative pressures on the river reach and the interventions required to achieve Good Ecological Potential under the WFD.

9.3.3 Eels

Since 2015 we have carried out a programme of assessment to determine the effect of our abstractions on Eel passage. Protection of eels and other species is not expected to have any impact on our supply demand balance but the information gained through these assessments has enabled us to gain a greatly improved understanding of the water environment in which we operate, including valuable data on fish populations and opportunities for creation of biodiversity enhancements. We are working in partnership with the European Sustainable Eel Group, Wildlife Trusts and Rivers Trusts to help deliver these benefits, using our innovative Biodiversity Index approach to measure the benefit that our actions create for the environment.

9.3.4 Invasive Species

In February and March 2017 the Environment Agency issued position statements on the management of potential impacts from transfer of invasive non-native species through raw water transfer systems. For existing systems that are already in use, this management approach is anticipated to be delivered through a risk assessment and longer-term planning for how any potential transfer of invasive species could be prevented or mitigated and this has been reflected in the WINEP. No new transfers are currently proposed in this WRMP19 for water bodies that are not currently connected and assessment of the risk of options has included an appraisal for each option of the risk that this may represent in transferring alien invasive species between water bodies.

9.3.5 Future Investigations

As part of the more detailed development of understanding into sustainable abstractions and the sustainable management of catchments, EA has now identified through the WINEP3 programme a total of ten locations operated by Bristol Water that may require further investigation. These are abstractions that may potentially have an impact on other water bodies, although this has not yet been confirmed. Investigation into these abstractions and the impact they may have on the environment will therefore enable an informed assessment of whether it may be appropriate in future to reduce the rate of abstraction from these sources (whether to "recent actual" levels or another level). The total deployable output of these abstractions is 69.28Ml/day although the volume at potential "risk" would be expected to be a maximum of the difference between recent actual abstraction and deployable output, a total of 5.9 Ml/d. The abstraction assessments will also include potential effects on other water users, such as Internal Drainage Boards.

Sources for investigation of potential impact on the sustainability of current abstraction are shown below in **Table 9-1**. For the purposes of this plan, it has been assumed that the existing abstraction licences held by Bristol Water will continue in their current form for the duration of the planning period.

Table 9-1: Water supply sources under investigation in AMP7

Licence name/scheme name	Action	Complete by	Deployable output (Ml/d)	Annual Licensed Quantity (Ml/d)	Recent actual use (Ml/day)	Potential yield at risk (Ml/day)
P09R Spring	a	31/03/2022	7.30	13.29	6.77	0.53
P10R Yeo (P10R) at P26R	a	31/03/2022	26.88	60.27	41.97	0.00
P27R	a	31/03/2025	12.40	13.70	8.74	3.66
P39R,	b	22/12/2024	26.88	60.27	44.33	0.00
P40R, P35R	a	31/12/2022	1.40	2.19	0.91	0.49
R24R - R24Ra Group (not included in current DO calculation)	a	31/03/2022	2.40	4.11	0.00	0.00
P14R, 2 Boreholes	a	31/03/2022	7.90	15.10	13.31	0.00
River Yeo (P41R), P42R	b	22/12/2024	11.00	24.66	15.46	0.00
P43R	a	31/03/2022	2.40	3.29	2.26	0.14

Licence name/scheme name	Action	Complete by	Deployable output (Ml/d)	Annual Licensed Quantity (Ml/d)	Recent actual use (Ml/day)	Potential yield at risk (Ml/day)
P30R Borehole and Spring (Pond)	a	31/03/2022	2.30	2.60	1.21	1.09
SUM						5.9

a = investigation and options appraisal
b = adaptive management (focused on flow changes in compensation flow, without impact on deployable output)

9.4 What do customers think about environmental protection

During our customer engagement activities customers were asked about our work for environmental protection and enhancement. The valuation data around the environment is inconclusive, largely because customers have been asked varying questions on issues relating to the environment. In general, customers don't seem to place a high priority on the environment in valuation studies, nor do they prioritise it in qualitative studies.

In contrast, data from the online customer panel (which is an ongoing process) indicated that 92% of participants stated that work to improve the environment, focusing on the quality of lakes and water sources as important and 81% of respondents said 'reducing carbon emissions by half' is also important. From the annual survey 'Help protect the environment' has been ranked in the middle of customers priorities since 2015, with 93% of customers saying it is very or quite important. This is one of our lowest performing areas since 2014 with 59.7% of customers believing we perform very well or quite well.

To help build on this, we hosted a specific 'Environmental Resilience co-creation' workshop[9] with local stakeholders who work in environmental and recreational organisations, seeking opinions, new ways to operate and a better understanding of the wider aims of these organisations. One of the key priorities identified was that we should work more towards a holistic approach to the water environment, considering water flows, fish and eel conservation and promoting people and wellbeing. We believe that our customers support the principle of environmental enhancements, but that these need to be communicated clearly and measured well. During the consultation phase of our draft WRMP19, environmental issues were explicitly referenced by only 6% of our customer respondents and focused on the effects of abstraction on the water environment and the need to consider renewable energy opportunities to reduce the carbon footprint of water supply.

[9] Facilitated Dialog by Design, November 2017

10 Climate Change

Section Summary

Climate change will have a material impact on the water industry as it affects both the available water from the environment and customers' need for water. We have undertaken studies into how and where predicted climate change impacts may affect the water available to us from the environment. Our most recent work shows that the impacts are likely to be less than forecast in WRMP14; our work then showed a loss of output of 17Ml/d in 2040 and this has now reduced to a forecast loss of 7.1 Ml/d by the end of 2045, due to the nature of our catchments and water sources which benefit from the more intense winter rainfall events predicted in a changed climate. This is clearly a better situation for us and our customers as it means we are less likely to need to invest capital in large new supplies.

We recognise that prediction of climate change impact is still a new science and the rate of climate change is uncertain, so we need to keep forecast impacts under review. In recognition of the potential sensitivity to climate risks, in accordance with latest guidance we commissioned a vulnerability assessment, updated from WRMP14, which shows that our system has Medium vulnerability. This is a change from the High rating in WRMP14 and is largely due to making most appropriate use of the latest UKCP09 impact data.

Despite only having a Medium vulnerability we have used a detailed Tier 3 assessment of the impact, as we wished to examine more closely the potentially significant change from High risk to Medium. We are satisfied that the change is appropriate under current guidance.

10.1 Introduction

To support the WRMP14 a full climate change vulnerability assessment was undertaken to identify the potential vulnerability of our sources to the effects of climate change, and identify the appropriate assessment method to use to determine the likely effects of climate change on deployable output.

The work carried out for WRMP14 used the UKCP09 climate change scenarios for the 2030s. The Environment Agency WRP Guideline (July 2018) and supplementary climate change guidance (Environment Agency, April 2017) has recommended that the effects of climate change on deployable output in the 2080s should be assessed, as opposed to the 2030s. In addition, a change to the scaling factor process has also been recommended. We have therefore reviewed and updated our climate change assessment to reflect these changes in guidance.

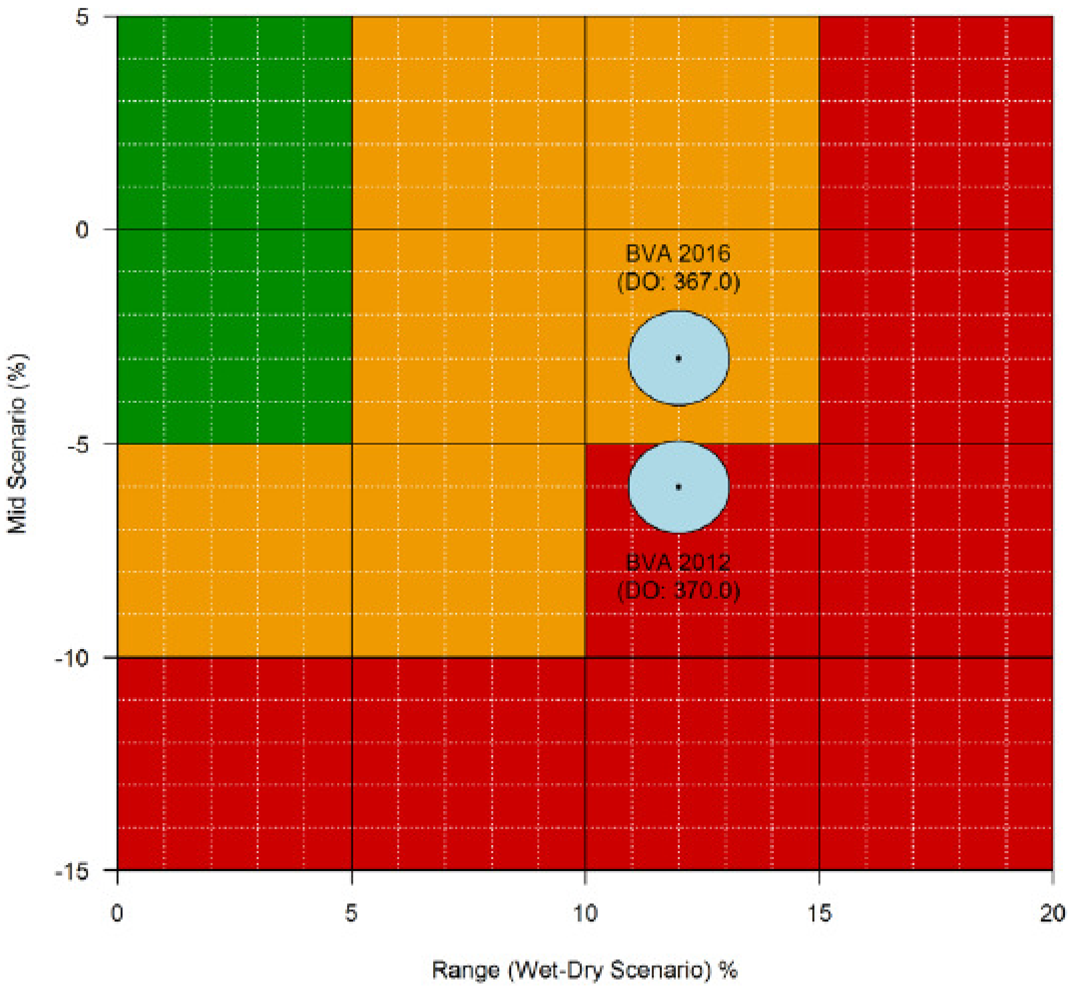
10.2 Update of the Climate Change Basic Vulnerability Assessment

The basic vulnerability assessment is the first level of the tiered approach to assessing climate change vulnerability, developed as part of the Environment Agency/ UKWIR *Climate change and water supply planning project* (Environment Agency 2013). The vulnerability assessment is qualitative and is completed based on information already available on the water resource zone and system vulnerabilities. The aim of the assessment is to identify whether the WRZ is classed as 'Low', 'Medium' or 'High' vulnerability to future climate change, which then influences the methodology adopted for the climate change impact assessment.

A review and update of the basic vulnerability assessment for Bristol Water was carried out by HR Wallingford. Full details of the basic vulnerability assessment are reported in HR Wallingford's technical report. This assessment of the most up to date information, including the outputs of the WRMP14 climate change assessment and the updated Drought Plan, concluded that the overall vulnerability of the WRZ shows a medium vulnerability to climate change.

A magnitude versus sensitivity plot was generated for the Bristol Water WRZ, using data from WRMP14. Magnitude was defined as the average DO impact on annual average DO. Sensitivity was defined as the percentage range in annual average DO impact between the lowest and highest DOs modelled as part of the WRMP14 climate change assessment. The magnitude versus sensitivity plot is shown in **Figure 10-1**. The red squares refer to high vulnerability, amber squares to medium vulnerability and green to low vulnerability. The results of both the updated vulnerability assessment (BVA 2016) and the vulnerability assessment carried out to inform WRMP14 (BVA 2012) are shown on the plot.

Figure 10-1: ***Magnitude versus sensitivity plot for Bristol Water for the 2030s. Results are shown for this BVA (BVA 2016) and for the BVA undertaken for the WRMP14 (BVA 2012)***



In WRMP14 our vulnerability was classified as 'High'. The updated available information reviewed for BVA update demonstrates that the vulnerability of the Bristol Water system to climate change is 'Medium'. This is due to the change in the reported 'mid' scenario between the WRMP 2009 and the WRMP 2014, which is as a result of the climate change values calculated for the WRMP 2009 not having used the UKCP09 climate change projections.

10.3 Climate Change Assessment Methodology

10.3.1 Modelling approach

A more detailed 'Tier 3' approach, as set out in the Environment Agency supplementary information (April 2017), has been used to assess the likely effects of climate change on the Bristol Water WRZ in the 2080s, even though the WRZ has been assessed as being medium vulnerability. The more detailed approach was selected because it is consistent with the methodology used in WRMP14, and the models and processes were available and relatively straight forward to update.

10.3.2 UKCP09 scenarios

The 10,000 climate change projections for the 25km^2 grid cell 1582 (Severn river), for the medium emissions scenario in the 2080's were sub-sampled using Latin Hypercube Sampling (LHS) to provide a representative sub-sample of 100 projections. The distributions of the 100 LHS selected samples within the full set of 10,000 for the 2080s medium emissions scenario was assessed to be relatively even, meaning that the sample is a relatively reliable sub-set of the full UKCP09 projections. This was in accordance with best practice.

10.3.3 Hydrological modelling – deriving surface water flow factors

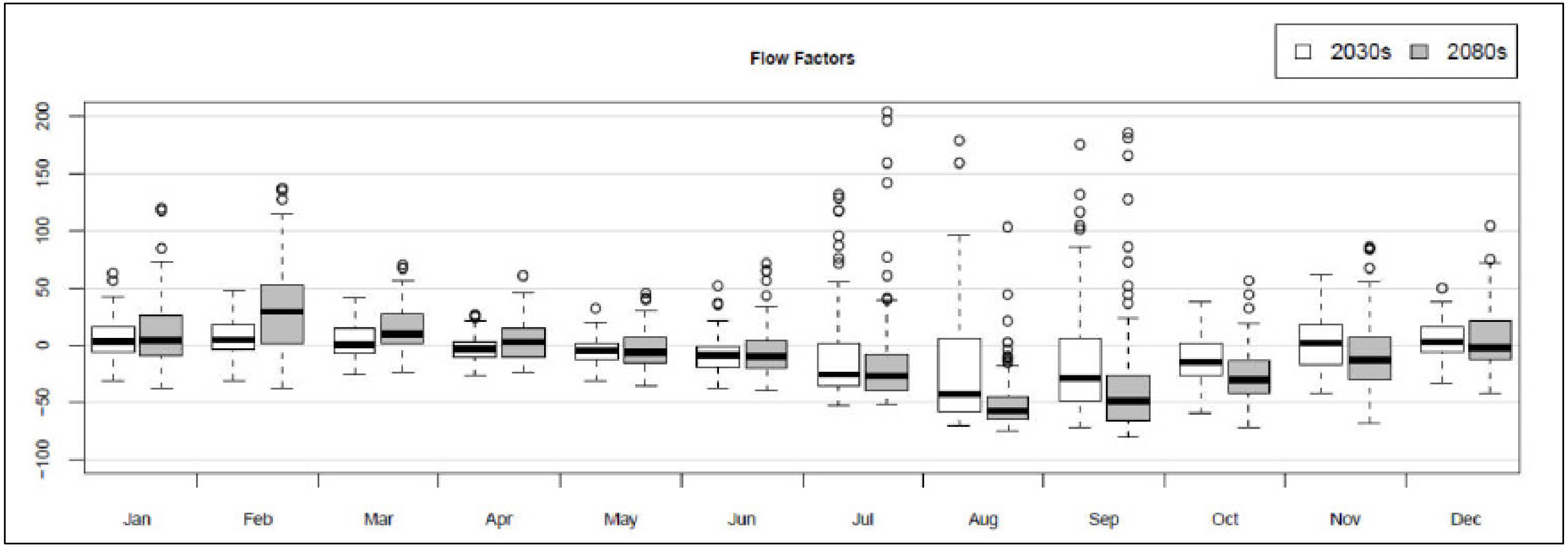
Bristol Water has five rainfall runoff models (HYSIM) covering our key water sources within our WRZ. These were provided to HR Wallingford in order to complete the climate change assessment work.

Each model was run for all of the 100 LHS UKCP09 projections. The flow outputs for each model were then processed to create a data set of flow factors, describing the future flow series as a percentage change from the simulated baseline flow series for each month of the year. The results of this for the baseflow components and the surface flow components are discussed in **Sections 10.3.4**.

In the 2080s projections, the overall flow factors for each HYSIM model show a similar pattern of changes in flows as for the 2030s; increased flows in winter and decreased flows in summer. The changes in the 2080s are a little more pronounced, i.e. the increase is greater in winter and the decrease is greater in summer in the 2080s compared to the 2030s. There is also a slight variation in the range of projections – in general the 2080s present a greater range of flow changes in winter than in the 2030s but a lower range of projections in summer.

An example of the plots produced showing the overall flow factors for one of the five HYSIM models is shown in **Figure 10-2**.

Figure 10-2: ***An example boxplot for one of the five HYSIM models showing the overall flow factors from 100 LHS UKCP09 medium emissions climate projections for the 2030s and 2080s for total flow (percentage change in monthly average flow)***



10.3.4 Hydrological modelling – deriving groundwater flow factors

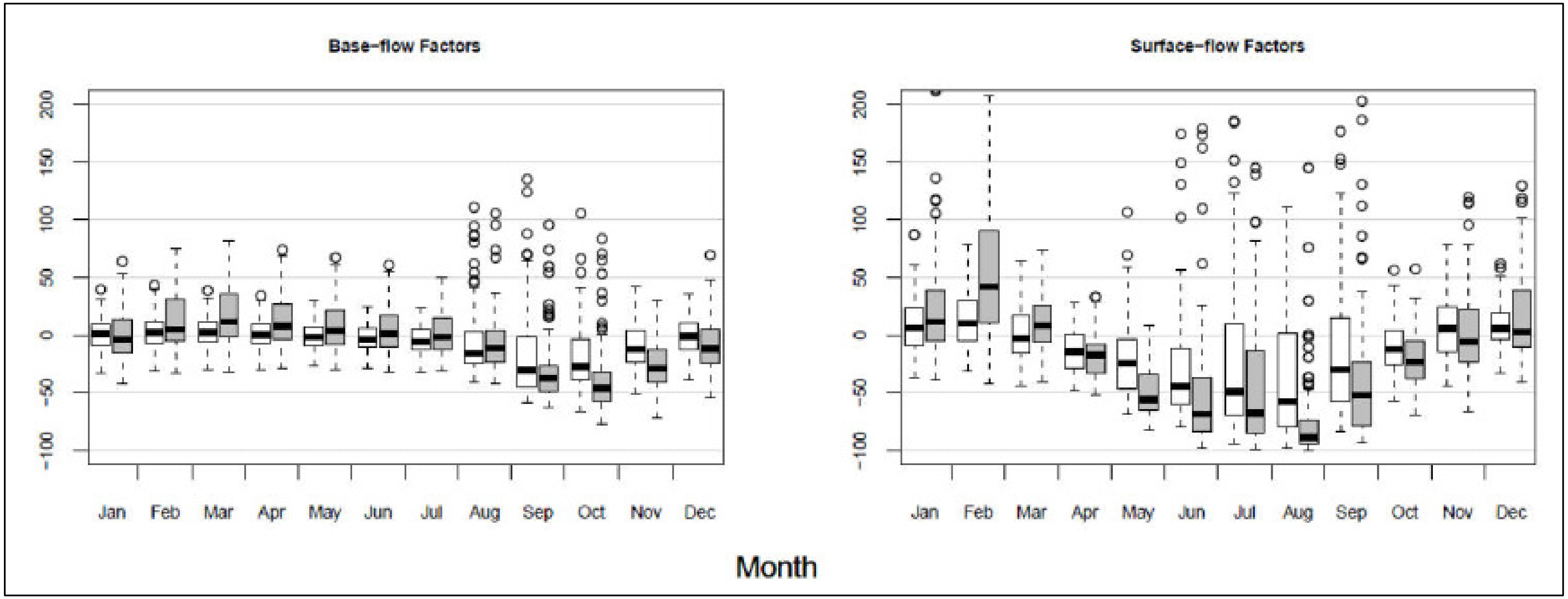
Approximately half of our groundwater sources are derived from deep groundwater that shows little or no variation in dry weather yield in relation to annual variations in climate. However, the remainder consists of shallow springs in the local fissured limestone, or shallow wells, that may respond more rapidly to climate conditions (although not as rapidly as surface waters).

To account for the impact of climate change on spring sources, HR Wallingford used a hydrograph separation method (Gustard *et al* 1992) to split the river flow hydrograph into its baseflow and surface flow components. The baseflow component was then able to be used as an approximation of the response of the spring sources to climate change.

This method was applied to the baseline time series and all future flow time series for each HYSIM model. Flow factors were then created by calculating the change in mean monthly flow from the baseline baseflow time series to each future baseflow time series. An example of the resulting baseflow and surface flow factors can be seen in **Figure 10-3**. For comparison, the results for the 2030s are presented alongside the results for the updated 2080s assessment.

Overall, the baseflow factors exhibit a dampened change compared with the surface flow factors. The seasonality of the changes in flow is reduced, with the largest flow reductions in September to November. This is a reflection of the lagged catchment response of baseflow compared to the more rapid response of surface flow.

Figure 10-3: ***An example boxplot for one of the five HYSIM models showing the overall flow factors from 100 LHS UKCP09 medium emissions climate projections for the 2030s and 2080s for baseflow and surface flow (percentage change in monthly average flow)***



10.4 Assessing the effects of climate change on deployable output

The flow series generated by HR Wallingford for each of the 100 UKCP09 medium emissions projections for the 2080s for each of the aggregated catchment groups used by Bristol Water within the Mass Balance Model were used to estimate a deployable output value for each of the 100 UKCP09 scenarios assessed. The findings of this climate change assessment in this sub-section are shown by comparison to the 1933/34 worst historic drought DO calculated value of 352.56 Ml/d reported in the draft plan rather than the 1 in 200 year DO value of 342.53 Ml/d in the supply forecast for this final plan. When applying the EA climate change supplementary guidance (April 2017) to the 1 in 200 year DO value it resulted in the impact of the reduced 1 in 200 year DO value being discounted against the climate change impact on DO. The implication of this was to reduce our resilience to the 1 in 200 year design drought through the planning horizon. In order to maintain resilience to the 1 in 200 year design drought event, and adopt the precautionary approach that climate change could impact this event in a similar way to the 1933/34 event, we have applied the same reductions in DO as calculated in the draft WRMP assessment. In developing this approach we consulted with HR Wallingford who advised that this precautionary approach was appropriate given the uncertainty associated with the climate change scenarios used.

As set out in **Section 6.1.2,** HR Wallingford updated the Mass Balance Model to enable a number of scenarios to be run as a ‘batch’, importing a given flow time series, calculating the DO for the user defined assessment criteria, storing the results and some key metrics for each run and then moving onto the next flow series. This process was used in the Mass Balance Model to assess all 100 climate change scenarios, and calculate a deployable output volume for the Bristol Water WRZ associated with each scenario.

The graph in **Figure 10-4** shows the distribution of the DO volumes modelled for each of the 100 climate change scenarios assessed. The ‘best estimate’ climate change scenario has been highlighted. This is the scenario closest to the overall data set average. This suggests that DO in the 2080s will be 342.46 Ml/d (i.e. a reduction of 10.10 Ml/d compared to the 1933/34 DO value). For comparison, the scenario closest to the 1933/34 DO of 352.56 Ml/d is also highlighted.

The graph in **Figure 10-5** shows the distribution of the change in DO volume, compared to the 1933/34 DO value. This shows that the effects of climate change by the 2080s range from a <u>reduction</u> in DO of up to 35 Ml/d to an <u>increase</u> in DO of up to 30 Ml/d. The ‘best estimate’ for the effect of climate change in the 2080s has been selected as the closest scenario to the overall average of the data set, and is just over 10 Ml/d lower than the 1933/34 DO. The uncertainty around the climate change ‘best estimate’ is captured in headroom and has used all 100 climate change scenarios to inform the uncertainty distribution used in this assessment. See **Section 11** for more details on the headroom assumptions.

Figure 10-4: ***Deployable output associated with each of the 100 UKCP09 climate change scenarios modelled***

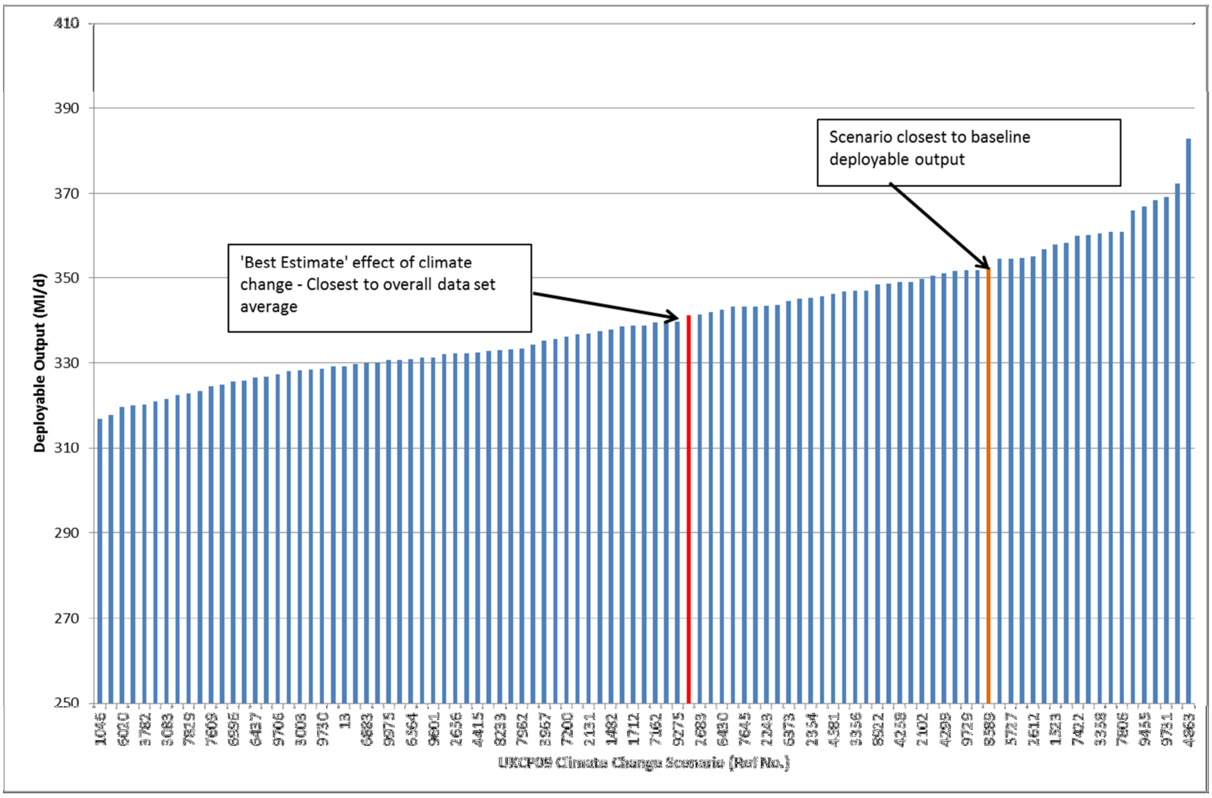
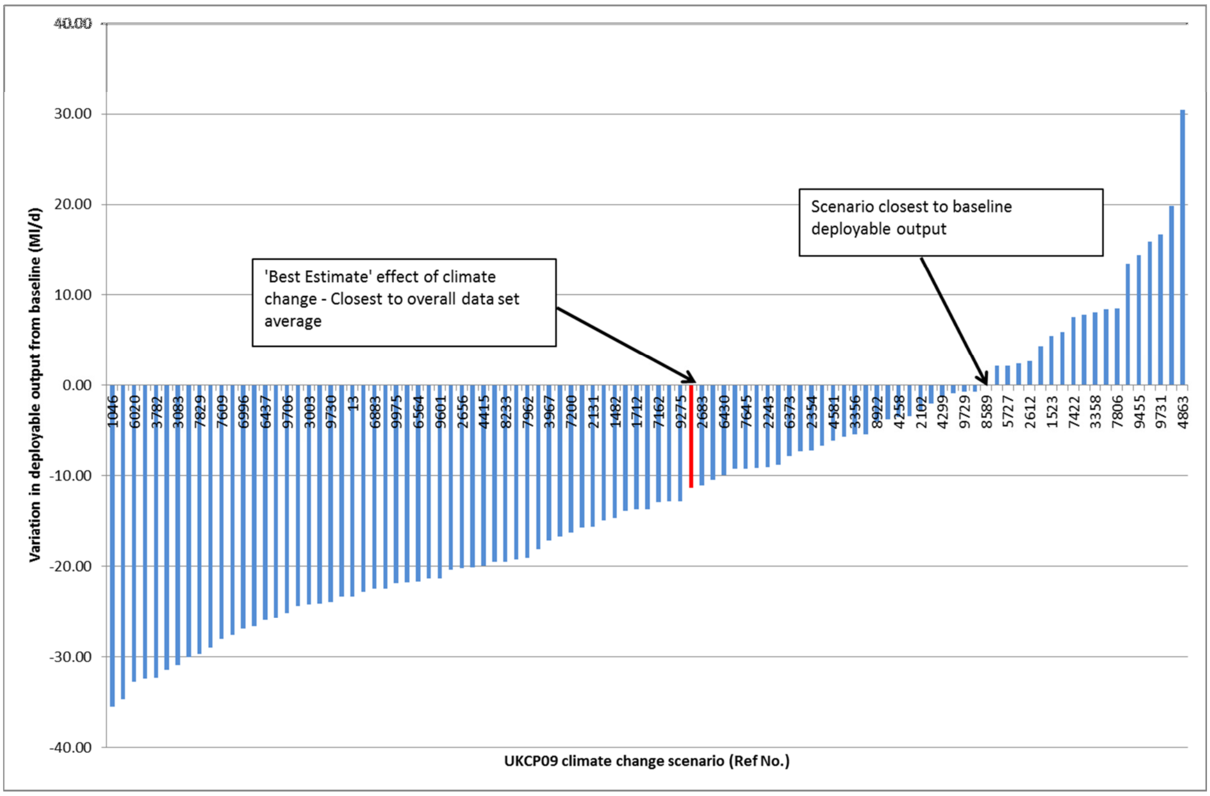


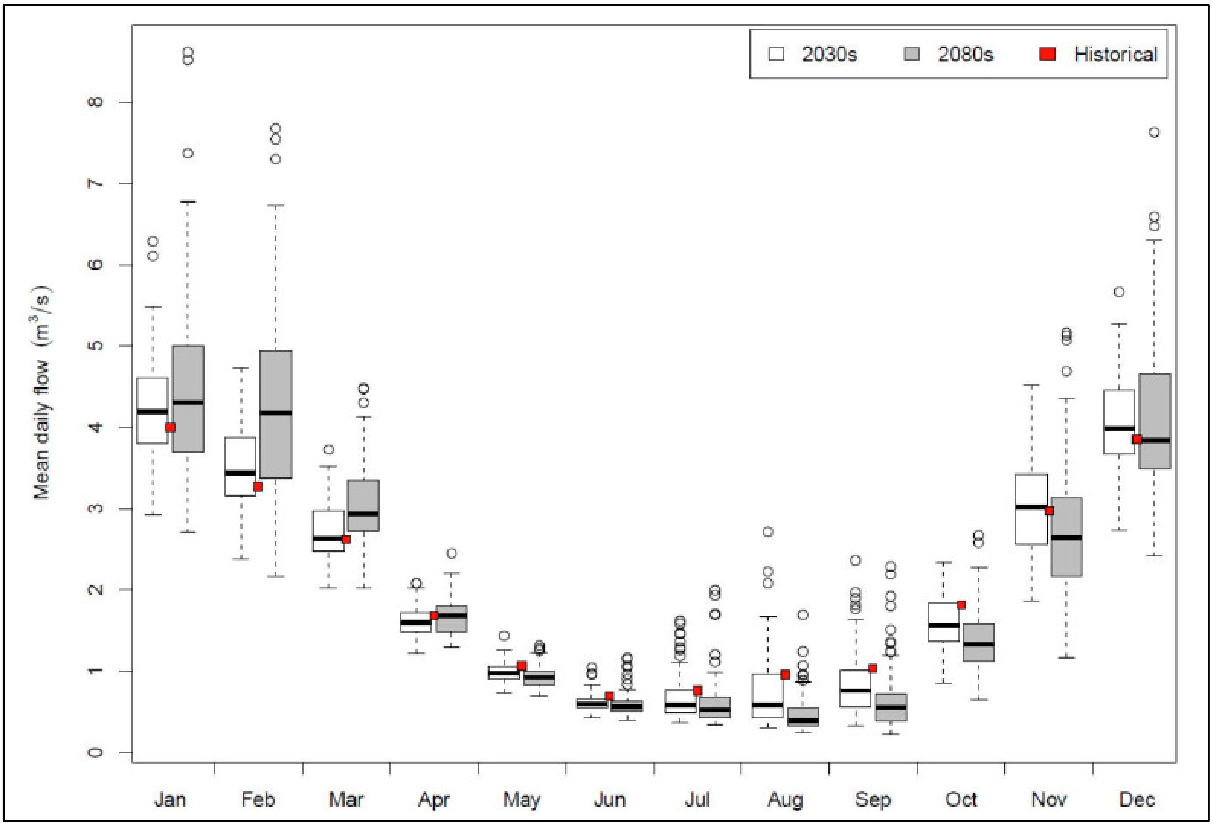
Figure 10-5: ***Change from baseline deployable output for each of the 100 UKCP09 climate change scenarios assessed***



The reduction in the 1933/34 historic drought deployable output of approximately 10Ml/d by the 2080s is similar to that forecast in the WRMP14 for the 2030s, where a reduction of approximately 12 Ml/d was reported. This may seem slightly counter-intuitive at first as it could be expected that the 2080s would result in a much more severe impact from climate change. A comparison of the impact on flows for the Mendip Group for the 2030s and the 2080s was carried out to better understand this result. The graph in **Figure 10-6** shows the results of this assessment.

In the 2080s in January to April the median flows are projected to be higher than those projected for the 2030s. The range of projections during these months is also greater. Between May and July, median flow projections are either very similar or slightly lower in the 2080s compared to the 2030s. The summer recession continues into August and September in the 2080s projections; reflected by the lower median and range of projections in flow. The flows in the summer months are already small (often less than 1m^3/s) and therefore the additional changes in temperature and precipitation beyond the 2030s to the 2080s have only a modest additional impact on flows. The 2080s projections indicate a delayed recovery in flows in October to December. However, in the context of the Bristol Water system and reservoir response, the increased projected flows in late winter (in January and February in particular) are likely to compensate for this.

Figure 10-6: Comparison of the impacts on river flows for the Bristol Water Mendip Group for the 2030s (from WRMP14) and 2080s medium emission climate change projections



When scaling back these impacts through the WRMP planning horizon, as set out in the Environment Agency WRPG supplementary information (April 2017), the move to the 2080s leads to a significant *reduction* in the climate change impacts realised for each year in the planning horizon. The reason for this is that the average increase per year from the baseline to the 2080s is less than from the baseline to the 2030s, and reflects the combination of the Bristol Water system characteristics and the 'wetter winters/drier summers' signal in the newly used UKCP09 projections.

10.5 Levels of service and climate change

The climate change assessment undertaken for the WRMP19 has not assessed in detail the likely effects climate change could have on customer levels of service in the context of each of the 100 climate change scenarios. The potential changes resulting from the effects of climate change under some of the more extreme scenarios could result in the Bristol Water WRZ being operated differently. A detailed assessment of the likely effects on levels of service is therefore not considered to be appropriate or particularly meaningful in the context of climate change analysis. The likely effects of climate change on actual levels of service have been included in the assessment carried out and reported in Section 16.2.1. This assessment includes the best estimate climate change assumption and the allowance for climate change uncertainty in the headroom assumptions used.

10.6 R01

For this WRMP we have assumed no change to the DO from the R01 as climate change continues to not affect this resource, therefore the resource is constrained by licence, not climate change. This is in agreement with Severn Trent Water's assessment. We will continue work closely with the major abstractors on the Severn through the Severn Working Group to ensure that this remains the case.

10.7 Effects of Climate Change on Water Resources Zone Supply

The likely effect of climate change on deployable output has been determined for the 2080s through the assessment process set out in **Sections 10.3** and **10.4**. In order to account for the effects of climate change across the 25-year planning period, a scaling methodology is applied to scale back the effect of climate change.

The Environment Agency supplementary information on climate change assessment (April 2017) sets out the methodology for this process. This has changed since the WRMP14 submission due to the new focus on the 2080s for the climate change assessment (as opposed to the 2030s) and the recommendation to scale back to 1975 (as opposed to the start of the planning period). This change in approach reduces the gradient of the climate change impact at the beginning of the planning period, but also results in an immediate loss of DO at the start of the planning period to account for the fact that some climate change has already occurred.

The graph in **Figure 10-7** shows the resulting forecast effect of climate change on deployable output over the 25 year planning period from 2020/21 to 2044/45. The new scaling methodology results in a reduction of 4.6 Ml/d to deployable output in the first year of the planning period (2020/21). This rises to a reduction of 7.1 Ml/d by 2044/45. Although there is now an immediate effect of climate change at the beginning of the planning period, the overall impact of climate change on deployable output across the planning horizon is not as significant as the forecast presented in the WRMP14, where the forecast effect of climate change by 2039/40 was a reduction of 17Ml/d to deployable output. **Table 10-1** summarises the forecast effect of climate change when the likely effects on DO are applied to the revised draft plan 1 in 200 year drought deployable output value (342.53 Ml/d) at the beginning of each 5-year AMP period across the 25-year planning period.

Figure 10-7: Scaled reduction in deployable output as a result of climate change (2020/21 to 2044/45)

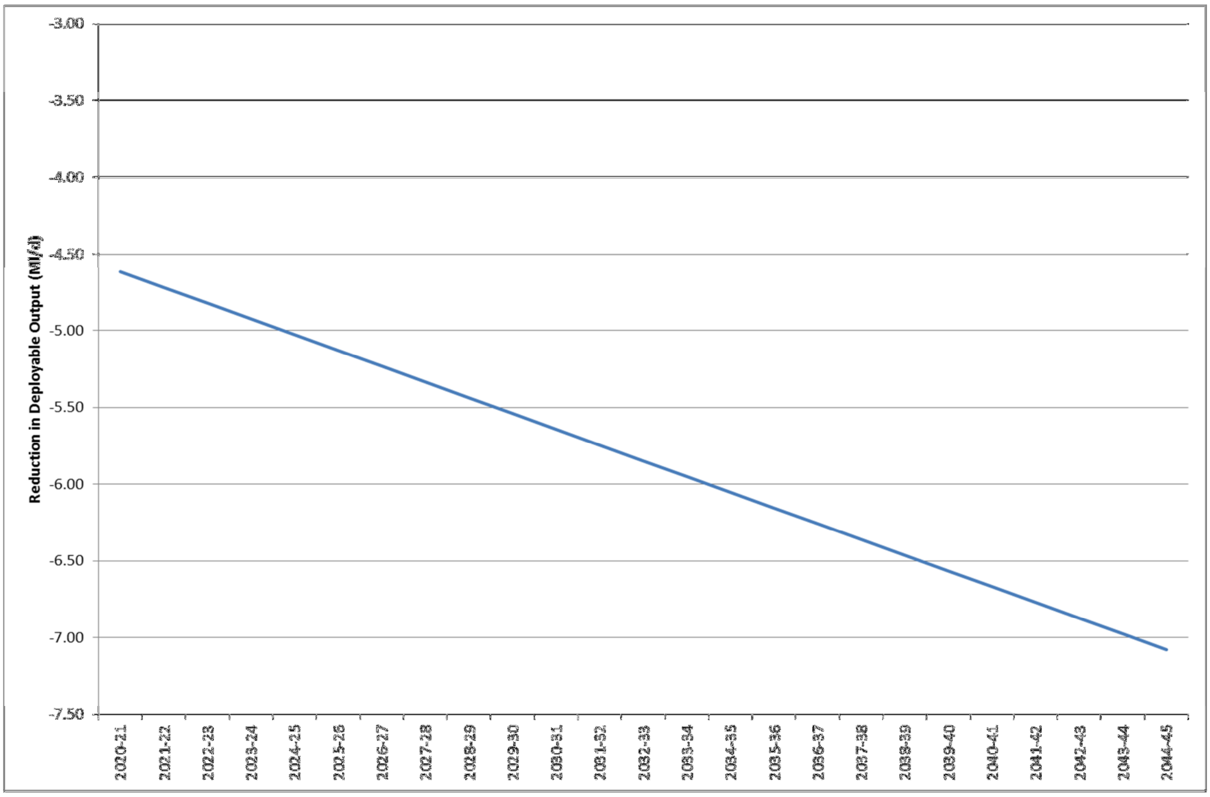


Table 10-1: Effects of climate change on deployable output across the 25 year planning period

	AMP7 2020/21	AMP8 2025/26	AMP9 2030/31	AMP10 2035/36	AMP11 2040/41	End of forecast 2044/45
Scaled climate change effect on 1 in 200 year DO	-4.6	-5.1	-5.6	-6.2	-6.7	-7.1
Revised 1 in 200 year DO due to climate change assessment	337	337	337	336	336	335

10.8 Secondary effects of climate change

In addition to the potential effects on water available for supply, climate change could have secondary implications in terms of physical effects such as water quality, flooding, extreme weather and non-physical effects such as increased energy prices and supply chain impacts. These potential risks to the business are addressed via the 2019 Business Plan.

11 Target Headroom

Section Summary

Because water resource planning is a long-term process and measures cannot normally be implemented quickly that can address a sudden deficit in water supply, companies manage this risk through inclusion of headroom in their supply-demand balance. Headroom calculation is a risk-based approach: it is not possible to create a plan that is resilient to any conceivable scenario, but a headroom planning approach can address the residual risk on a probabilistic basis, thus ensuring that investment is not made too early (and hence is inefficient) or too late (and hence subjects customers to an unacceptable level of risk). Our headroom calculations were carried out by external consultants in accordance with the latest guidance and our risk profile takes a gradually increasing profile of risk across the planning period.

11.1 Background

Even though we use the most up-to-date technology, methods and data available to produce our supply and demand forecasts, there is still a certain amount of uncertainty in all these forecasts. Therefore we are required to analyse and quantify the variability and uncertainty that exists within our calculation to develop the supply demand balance. We identify a 'target headroom' volume as a means of allowing for the uncertainty in the supply demand balance. This is a buffer between supply and demand.

A probabilistic approach to determining target headroom in the Bristol Water WRZ was used to develop the WRMP14, using the UKWIR (2002) methodology *'An Improved Methodology for Assessing Headroom'*. In the context of our Problem Characterisation modelling complexity category being identified as 'Low level of concern', we have continued to use this headroom assessment methodology as an appropriate current approach to allow for the assessment of uncertainty in the supply demand balance.

In reviewing the headroom assessment carried out for WRMP14, it was identified that some improvements could be made in terms of the Monte Carlo model used for the headroom assessment, and the assumptions used relating to the uncertainties within the supply demand balance. A full review and update of the headroom assessment process was therefore carried out with the support of consultants Atkins. Full details of this work are available in the Atkins technical report (Atkins, October 2017). An overview of the approach used and the results is provided in the following sections.

11.2 Methodology

The headroom model has been developed using the principles of the UKWIR (2002) methodology. The model is based in Excel and uses the Oracle Crystal Ball[10] software add-in to undertake the Monte Carlo simulations. The model was designed with a structured data entry sheet and model output sheet to ensure full transparency of input and output data. The model calculated headroom uncertainty for the whole of the planning period from 2016 through to 2050 with outputs expressed as a probability distribution function. The absolute value of target headroom is then selected according the adopted level of risk the company wants to take for each year of the planning period.

The headroom uncertainty is calculated on a water resource zone basis, for the dry year annual average (DYAA) planning scenario. The components of uncertainty within the supply demand balance are divided into two main areas; supply side and demand side. These are then sub-divided into respective supply or demand side components as set out below:

Supply side headroom components:

- S5 – Gradual pollution (surface water and groundwater considered)
- S6 – Accuracy of supply side data (surface water yield & groundwater yield)
- S8 – Impact of climate change on DO

Demand side headroom components:

- D1 – Accuracy of demand data (meter accuracy)
- D2 – Demand forecast variation (economic and population growth)
- D3 – Impact of climate change on demand
- D4 – Uncertainty over demand management options

As required by the Environment Agency's Water Resource Planning Guideline (April 2017), the headroom analysis has made no allowance for the risk of time-limited licences not being renewed (covered under component S3: uncertainty of the renewal of time-limited licences) or licences being revoked due to sustainability reductions (covered under components S1: vulnerable surface water licences, and S2: vulnerable groundwater licences). In addition, Bristol Water do not have any Bulk Imports (S4) we consider to be uncertain or at risk, and so this component has not been used in our analysis. A summary of the assumptions use to assess the uncertainty for each supply side and demand side headroom component is provided in the following sections.

11.3 Supply side headroom components

S5 – Gradual Pollution

This component represents the risk of our groundwater source P11R Sub and Main becoming polluted due to hydrocarbon contamination from a known source within proximity (cone of influence) to the site. This could result in a sudden pollution event that could not be reversed, resulting in the contamination of the source and subsequent abandonment.

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[10] http://www.oracle.com/us/products/applications/crystalball/overview/index.html

S6- 1/2/3 – Accuracy of supply side data

The uncertainty in component S6 is derived using the factors that determine the constraint on Deployable Output (DO), for example hydrology, hydrogeology, abstraction licence or infrastructure. This component has therefore been divided into 3 sub-components to assess the uncertainty associated with each of Bristol Water's main sources of supply.

S6-1 – represents the uncertainty around the inflow data used to determine the yield of the Mendip Reservoirs. Data consists of Hysim rainfall runoff data from 1910 to 1959 and then recorded inflow data from 1960 onwards. The uncertainty associated with this data was assessed to be +/- 10% around the deployable output of the Mendip Reservoirs.

S6-2 – represents the uncertainty around the groundwater yield assessment and the construction of the operational drought curves used to define the deployable output of the sources. The methodology used to assess groundwater DO followed the UKWIR 1995 approach (A method for the determination of the outputs of groundwater sources). The uncertainty associated with this data was assessed to be +/- 10% around the total deployable output of the groundwater sources.

S6-3 – represents the uncertainty around the yield of the R01 during a dry year. It is assumed in the baseline deployable output assessment that the source is licence constrained, however, there is the potential for it to be resource constrained, and especially under a River Severn Drought Order should one be put in place by the Environment Agency. The uncertainty associated with this assumption was assessed to be a maximum reduction of 5% of the yield from this source. This is reflective of the 5% cut back under the River Severn Drought Order.

S8 – Uncertainty of impact of climate change

The uncertainty in component S8 has been developed using the UKCP09 climate change scenarios. The UKCP09 scenarios come in the form of 100 future DO scenarios for the year 2085. Each iteration of the Crystal Ball Monte Carlo analysis selects one of these projections at random (each considered equally likely). The difference between the current baseline DO (2017) adjusted to reflect the best estimate of the effect of climate change on DO and the selected 2085 projection is then scaled across the full planning horizon (using the EA recommended method) and the reduction in DO exhibited each year then calculated as the S8 climate change headroom addition.

11.4 Demand side headroom components

D1 – Accuracy of demand data (meter accuracy)

Component D1 is to allow for uncertainty due to meter inaccuracies. A normal distribution of uncertainty has been assumed for this component. The meters that measure abstraction are different to those used for calculating distribution input, so there is no correlation between components D1 and S6-2. D1 is also not correlated to S6-1 and S6-3 as these components are based on uncertainty of hydrology assessments, based on river gauging not flow meter data.

D2 – Demand forecast variation (economic and population growth)
The demand forecasts provided by Artesia Consulting, who have developed the demand forecast for Bristol Water's WRMP19, include separate forecasts for household demand and non-household demand. The D2 component therefore comprises two separate elements, D2-1 household demand uncertainty and D2-2 non-household demand uncertainty. The uncertainty around the D2-1 and D2-2 components is represented in the headroom model as a triangular distribution for each year in the planning period, with a minimum value equal to the difference between the lower and best estimates, a maximum value equal to the difference between the upper and best estimates, and most likely value equal to zero (i.e. no difference from the best estimate).

D3 – Impact of climate change on demand
Climate change is already included within the demand forecast, so only uncertainty around the impact of climate change has been included in this analysis. Component D3-1 is the % range of uncertainty around the impact on both Household and Non-household demands. The component is assumed as having a triangular distribution of minimum, most likely and maximum parameters derived by Artesia Consulting on behalf of Bristol Water.

D4 – Uncertainty over demand management options
The D4 component is used to describe the uncertain outcome of demand management measures and will be used in the calculation of the Final Planning headroom uncertainty only. It will be assumed that there is no uncertainty in the start date of new schemes; hence the D4 component is used to represent uncertainty in the savings of water efficiency measures, leakage and metering options only.

11.5 Headroom Uncertainty results

11.5.1 Company risk profile and baseline target headroom

The target headroom allowed for in the supply demand balance represents the level of risk that the company is prepared to take. After consideration of the baseline outputs, Bristol Water has proposed a standardised risk profile as shown in **Table 11-1.** This profile represents a balance between being overly cautious (which would be very expensive) and overly optimistic (i.e. accepting too high a level of risk). A glidepath of gradually reducing risk percentiles through the planning period will be adopted for the water resource zone in accordance with the EA WRPG due to the ability to more effectively plan for changes in the longer-term via 5 year cycles of the WRMP process.

The 95th percentile represents a 5% risk that available supplies will be unable to meet demands plus target headroom, the 90th percentile represents a 10% risk, the 75th percentile represents a 25% risk, etc.

Table 11-1: Headroom risk profile

Year beginning	2017 – 2025	2026 – 2030	2031 – 2035	2036 – 2040	2041 – 2045
AMP Period	6/7	8	9	10	11
Percentile	95th	90th	85th	80th	75th

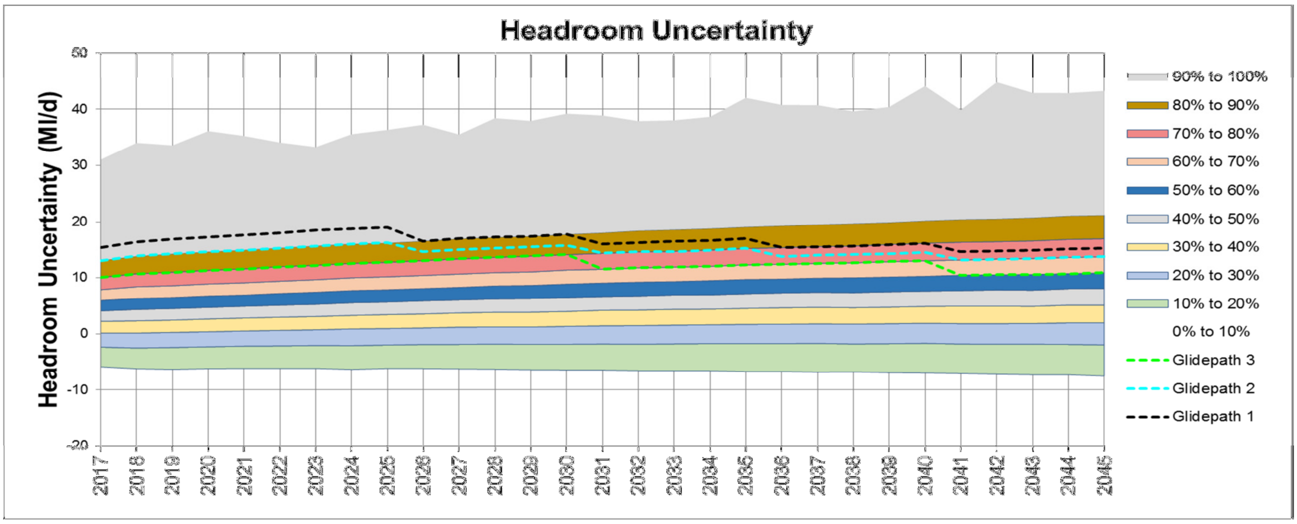
A baseline headroom analysis has been run for the Dry Year Annual Average (DYAA) planning scenario for the supply area. The outputs from the headroom analysis gives the probability distribution of headroom uncertainty for each year of the planning period for each headroom component, which are then combined to give a total headroom distribution for all components. The baseline target headroom values generated by the headroom model are presented in **Table 11-2** in five-year time steps.

Table 11-2: DYAA Target Headroom values for 2020-2045

	DYAA Target Headroom (Ml/d)				
Year	2021	2026	2031	2036	2041
Glidepath %	95%	90%	85%	80%	75%
Target Headroom Ml/d	17.7	16.6	16.0	15.4	14.7

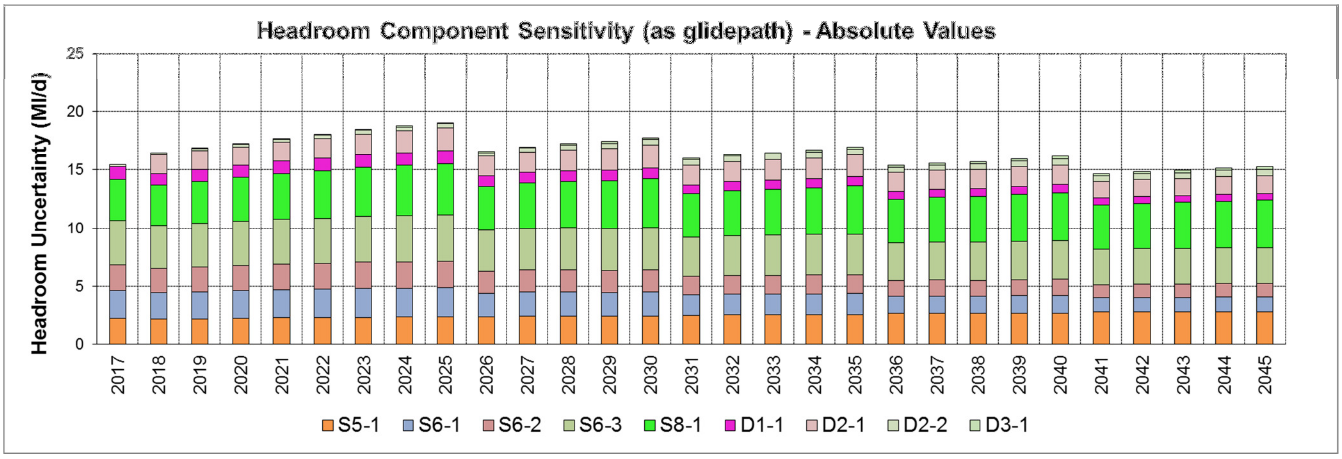
Figure 11-1 shows the headroom "plume plot" glidepath graph for baseline headroom uncertainty The graphs show the total headroom uncertainty distributions in 10% bands, including the selected glidepath (from **Table 11-1**).

Figure 11-1: Total headroom uncertainty for glidepath 1-3.



The individual target headroom components as Ml/d are presented in **Figure 11-2**. The results clearly show the highest level of uncertainty related to supply side components, in particular the effects of climate change.

Figure 11-2: Headroom uncertainty



11.5.2 Comparison with WRMP2014 Headroom results

The approach to assessing target headroom between WRMP14 and 19 has some significant differences as detailed in this Section. The input parameters for supply and demand components are presented in **Table 11-3** and **11-4** respectively. The overall approach adopted at WRMP19 is less risk adverse which has resulted in a significant reduction in the target headroom.

Table 11-3: Supply comments between WRMP14 and 19

Component code	Component description	Component application	
		WRMP14	WRMP19
S1	Vulnerable surface water licences A license that may be revoked or reduced because continued abstraction at or below the full licensed rate could potentially pose a threat to: • Minimum residual river flows: and/or • Environmental in-river or estuary needs; and/or • Surface water features e.g. lakes and wetlands. Or A license under which the rate of abstraction may need to be reduced to allow an increase in residual river flows.	Increased risk of longer Severn drought order	Not Applied

Component code	Component description	Component application	
		WRMP14	WRMP19
S2	Vulnerable groundwater licences A license that may be revoked or reduced because continued abstraction at or below the full licensed rate could potentially pose a threat to: • Minimum residual river flows: and/or • Environmental in-river or estuary needs; and/or • Surface water features e.g. lakes and wetlands. Or A license under which the rate of abstraction may need to be reduced to allow an increase in residual river flows	Not Applied	Not Applied
S3	Time-limited licences Licenses that expire at a given date but may be renewed (all or in part) at a future date by the Environment Agency.	Not Applied	Not Applied
S4	Uncertainty surrounding bulk imports A resource zone that has one of more bulk transfers into or form an adjacent water company or, a resource zone that utilises a source that is owned by another water company.	River Severn to R01 transfer risk failure	Not Applied
S5-1	Gradual pollution of sources causing a reduction in abstraction Surface and/or groundwater sources that are vulnerable to, or at risk from, gradual pollution and may therefore no longer be economic to maintain.	Risk to P11R Wells, P14R and P15R WTW inflow	Risk to P28R
S6-1	Accuracy of supply side data The accuracy of the WAFU figure depends on the quality (length/spatial resolution/reliability) of the data used in the modelling.	Climate constrained surface water resources	Uncertainty of Mendip Reservoir yield
S6-2	Accuracy of supply side data As above	Uncertainty of aquifer constrained groundwater sources	Uncertainty of groundwater yield assessment
S6-3	Accuracy of supply side data As above	Not Applied	Uncertainty around R01 yield
S7-1	Single source dominance and critical periods	Not Applied	Not Applied

Component code	Component description	Component application	
		WRMP14	WRMP19
S8-1	Uncertainty of impact of climate change The variation in source WAFU under climate change scenarios.	UKCP09 climate change uncertainty	UKCP09 climate change uncertainty

Table 11-4: Demand comments between WRMP14 and 19

Component code	Component description	Component application	
		WRMP14	WRMP19
D1-1	**Accuracy of sub-component data** The accuracy of the data used in the initial water balance calculation and in the demand forecasts	Uncertainty of meter accuracy	Uncertainty of meter accuracy
D2-1	**Demand forecast variation** The variation between the following demand forecasts: • Dry year annual average unrestricted daily demand (best estimate); • Dry Year annual average unrestricted daily demand – upper forecast; • Dry year annual average unrestricted daily demand – lower forecast.	Uncertainty in household and non-household demand forecast	Uncertainty in household demand forecast
D2-2	**Demand forecast variation** As above	Lumped with D2-1 for WRMP14	Uncertainty in non-household demand forecast
D3-1	**Uncertainty of climate change impact on demand** The variation in demand that can be expected under climate change scenarios.	Effect of climate change on demand	Effect of climate change on demand

Component code	Component description	Component application	
		WRMP14	WRMP19
D4-1	**Uncertainty of new demand management options** The uncertainty surrounding the effect of demand management schemes implemented within a resource zone.	Not Applied	Will be applied for final planning scenario headroom assessment

11.5.3 Reducing headroom uncertainty

As the planning period progresses we will seek to reduce the uncertainty regarding target headroom. As demonstrated in this section, climate change is the largest uncertainty in the headroom model. As climate change science is in a phase of rapid development, this understanding can be expected to develop over the coming five years for WRMP24.

12 Baseline Supply-Demand Balance

Section Summary

We have brought together all the outputs from the earlier sections to provide a Baseline Dry Year Supply Demand Balance from which we determine if any supply shortfall is forecast within the 25 year planning horizon.

Our supply demand balance shows, in the absence of any actions to close the gap, a small deficit of 0.87 Ml/d at the end of 2036 which rises slowly over the planning period to a deficit of 9.18 Ml/d by the end of 2045.

This situation differs from the forecast for WRMP14 and gives greater flexibility in the options available to address our future deficit. In the next sections we examine options for closing this small forecast supply demand gap in the most cost effective, resilient and environmentally acceptable way, to meet our customers objectives of affordable prices and reliable supply.

12.1 Background

The baseline dry year supply and demand data determined in the previous chapters has been used to produce a Baseline Dry Year Supply Demand Balance for the Bristol Water WRZ. All of the known changes to water available for use (WAFU) and the known baseline demand management policies have been included within these calculations. The baseline supply demand balance calculation is to identify whether our WRZ is predicted to have a supply deficit at any point over the 25-year planning period.

12.2 WRMP supply demand position

Our WRMP14 set out a position whereby there was a supply demand deficit from 2018 onwards. This was driven by a number of assumptions, the most significant of which was the need for a large industrial demand from 2018 onwards; this large demand has been put on indefinite hold. The review and update of all of the components of the supply demand balance to support the WRMP19 shows that a supply deficit is not forecast until 2035/36, and the volume of this deficit is significantly less than previously forecast.

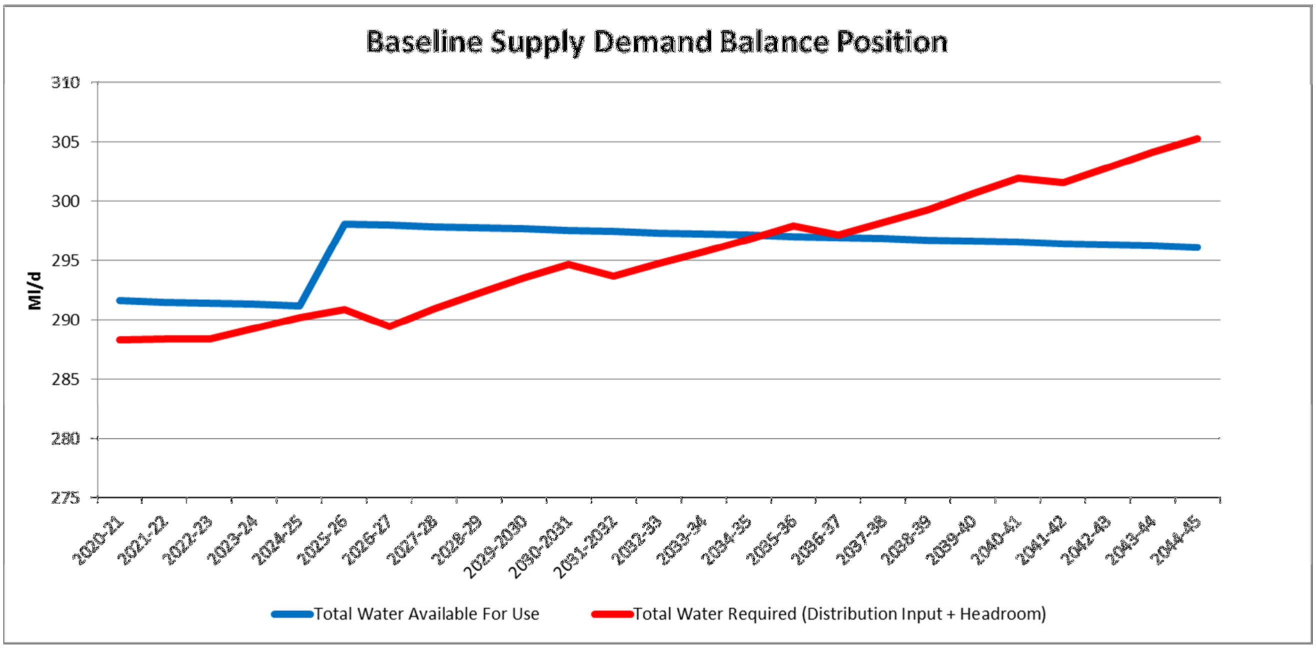
Figure 12-1 presents the baseline supply demand balance for the Bristol Water WRZ. It shows a gradual increase in distribution input (demand) over the planning period. This is largely a result of the forecast increase in properties and population over the planning period resulting in an overall increase in total consumption. When target headroom allowance is included on top of the distribution input volume, a small supply demand deficit is triggered in 2022/23. This supply demand deficit continues to increase across the planning period as distribution input increases and WAFU decreases, largely as a result of the effects of climate change on forecast deployable output. The overall effect is that the supply demand deficit is estimated to steadily rises to 12.79 Ml/d by 2044/45. The balance of supply for the dry year annual average planning scenario is summarised in **Table 12-1**.

As a supply demand deficit is forecast over the planning period, an assessment of the possible options available to meet this deficit is required. The options appraisal process is set out in **Section 13**, and the appraisal of the most suitable option solution is set out in **Section 15** with the final water resource and demand strategy set out in **Section 16**.

Table 12-1: Summary of the balance of supply across the 25-year planning period

	End of AMP7 2024/25	End of AMP8 2029/30	End of AMP9 2034/35	End of AMP10 2039/40	AMP 11- End of forecast 2044/45
Balance of supply (including headroom) Ml/d	1.03	4.11	0.36	-4.01	-9.18

Figure 12-1: ***WRMP19 baseline supply demand balance***



13 Options Appraisal

Section Summary

Working with our stakeholders we have developed a very wide range of possible options, alone or in combination, which could be used to close the forecast supply demand deficits. We show how these options have been assessed with a series of “filters” and widely consulted on to establish an agreed list of feasible, affordable and sustainable options.

In total around 150 separate options for closing the gap were initially developed including leakage reduction, demand management, improvements to production works and new resource/transfer options. Over the filtering/screening process this list was refined and reduced to 21 options which cover the same categories of leakage, demand management, production improvements and new resources/water transfers. In the initial screening stages cost was not used to eliminate options.

As part of the filtering process options have been systematically assessed against statutory environmental and social aspects as reported on in **Section 14**. For additional insight we have also assessed options against resilience criteria, carbon costs, ecosystems services impacts and, critically, against our customers views

The 21 remaining options were then further assessed through an engineering and cost estimation process to more closely define the supply benefit or demand reduction benefit and the socio-economic cost/Ml. This information has then been used in **Section 15** to develop a preferred programme of measures for WRMP19 to manage the supply demand balance over the 25 year planning period.

All options, the outcomes of the various screening processes and explanations of decisions are reported on in this document and in separate detailed reports available in **Appendix E, F, H, I and J**, this reporting is an essential part of transparency of decision making and allows a formal audit trail for inspection by regulators and other stakeholders.

13.1 Introduction

A comprehensive appraisal has been carried out to evaluate a wide range of options to determine a final suite of options for inclusion in the investment appraisal model to explore the optimal mix of options to address any identified supply-demand deficits over the planning horizon.

The options appraisal process adopted is fully compliant with statutory requirements and regulatory guidance. Where applicable, we have also applied national water industry methods developed by United Kingdom Water Industry Research (UWKIR) and/or the Environment Agency.

In line with the Final Water Resources Planning Guideline (July 2018), government and regulatory expectations and associated national guidance, our options appraisal process had the following aims:

- To demonstrate a systematic and auditable process for developing an appropriate set of options, moving from an "unconstrained" set of options to a set of "feasible" options through to a final "constrained" list of options;
- To develop the final constrained list of options through consultation with our regulators and relevant stakeholders;
- To integrate the statutory Strategic Environmental Assessment (SEA), Habitats Regulations Assessment (HRA) and Water Framework Directive (WFD) assessment processes into the options appraisal process; and,
- To integrate water supply resilience considerations into the appraisal process

Our options appraisal process reflects national guidance which advises that water companies should employ robust and objective screening criteria to assess the unconstrained list of options and filter this list to a smaller feasible list of options and finally a constrained list, providing justification for why particular options have been rejected during each stage of the process.

13.2 Methodology

13.2.1 Overview

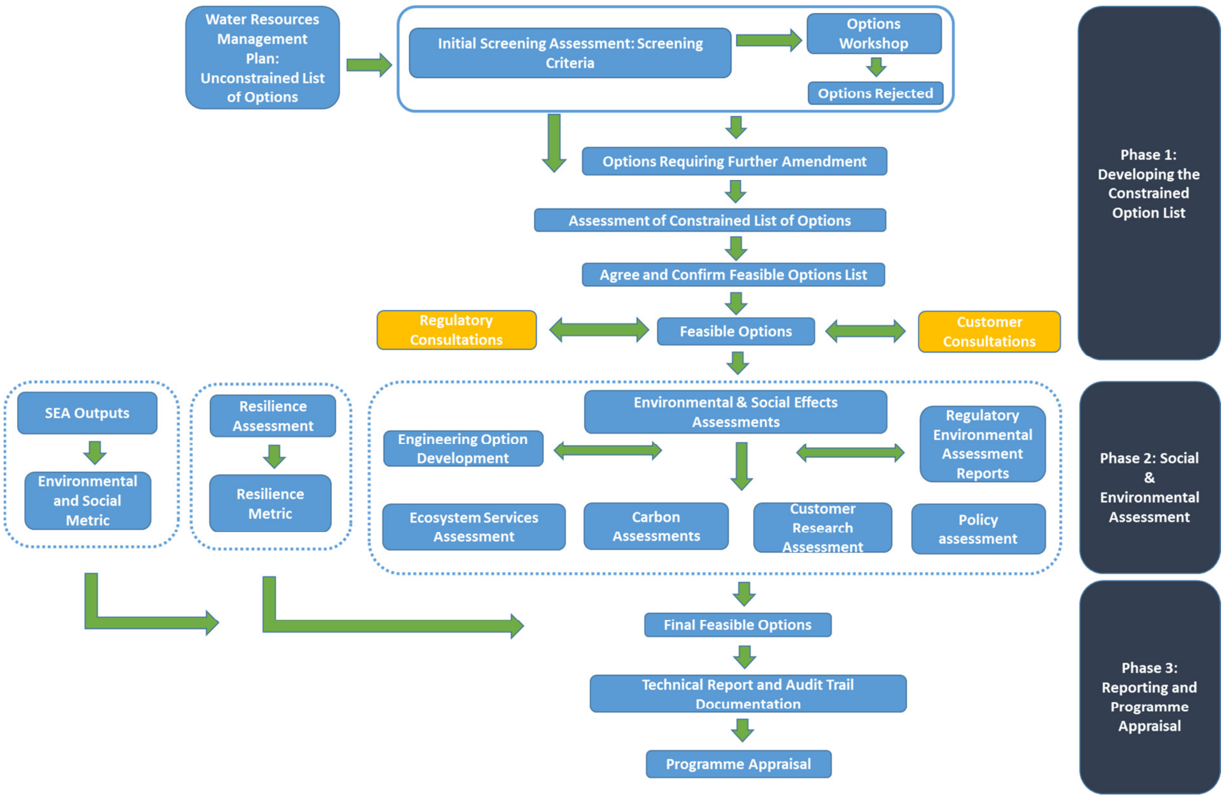
We developed our options following a sequential screening approach:

- Development of the unconstrained list of options.
- Assessment to determine the feasible list of options.
- A finer level of assessment to derive the constrained list of options.
- Further refinement of the options to determine the final constrained list of options.

The approach involved a multi-stage, screening process that included consideration of a range of criteria, including the statutory SEA, HRA and WFD assessment processes, technical and operational feasibility, resilience considerations and evidence from our customer research. The approach adopted provides an enhanced and rigorous screening process that ensures objectivity and consistency so as to avoid bias towards any particular option or option type.

Integration of the options appraisal process with the SEA, HRA and WFD assessment processes has ensured consistency between these inter-linked processes, with the screening criteria developed to explicitly reflect these statutory processes. The process also integrated the findings from our Sustainable Economic Level of Leakage (SELL) assessment. The appraisal approach was linked directly to the subsequent programme investment appraisal modelling process to ensure compatibility between the screening criteria and the optimisation criteria included within the investment appraisal model. **Figure 13-1** provides an overview of our option appraisal process

Figure 13-1: Option Appraisal Process Overview



13.2.2 Developing the Constrained Option List

Developing the constrained option list was undertaken in four key stages (**Figure 13-2**). The methodology follows a sequential approach with greater levels of analysis and assessment as the process proceeds:

- **Stage 1**: Develop the unconstrained list of potential options to help maintain a supply-demand balance. This includes demand management, leakage control and distribution management, water production and water resource options. This stage involved considering a wider range of alternative options with no assessment criteria applied to filter out any options.

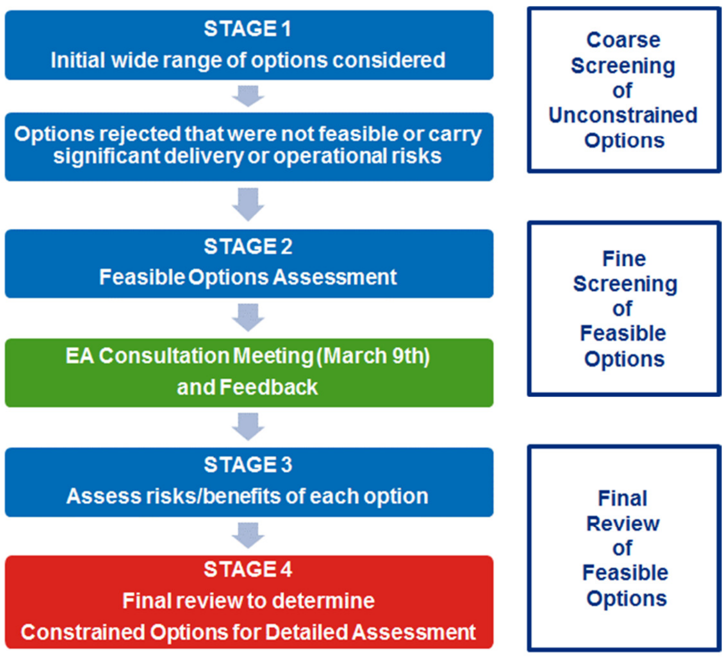
  The unconstrained list of options was then subject to a "coarse" screening process against a set of objective criteria which included regulatory and customer acceptability, technical feasibility, social and environmental implications, resilience and compliance risks. High risk options and those options assessed as not feasible were discounted at this stage of the process.

- **Stage 2**: Options passing through the coarse screening stage were considered to be feasible options and assessed through a “fine” screening process involving a wider and more detailed set of assessment criteria that built on the coarse screening criteria. The findings of the assessment were used to determine those options to be carried forward to the final stages of the appraisal process. The draft findings were discussed with the Environment Agency in March 2017 and feedback taken into account in finalising the options carried forward for the final stages of the appraisal process.

- **Stage 3**: The remaining feasible options were assessed in greater detail to understand their risks, costs and benefits. This resulted in some further options being rejected.

- **Stage 4**: A final review of the remaining options led to a final constrained list. These options were further developed and costed for consideration within the programme appraisal model.

Figure 13-2: Options Development Process



The assessment process was informed by evidence and dialogue with relevant planning, regulatory and operational teams within Bristol Water, including cross-company appraisal workshops and special interest sessions on particular option types (e.g. leakage control, catchment management, production management options).

The process was also informed by the outcomes of parallel assessment activities, including the SELL assessment, future metering policy and strategy, operational and maintenance strategies and wider strategic asset planning activities.

13.2.3 Stage 1: Developing the unconstrained options list and coarse screening

The unconstrained options list was developed through several activities, including a review of options identified for previous WRMPs, the generation of new options ideas from workshops with our operational and strategic planning staff and a review of regulatory and best practice guidance.

An initial unconstrained options list was reviewed through a series of structured, externally facilitated workshops with operational, engineering, regulatory and strategic planning staff along with external water resources and environmental assessors to ensure that all potential options were identified.

The coarse screening process involved assessment of each unconstrained option against the criteria set out in **Table 13-1.** Key considerations were to identify any over-riding constraints to option promotion, development and implementation (e.g. legislation or policy, unacceptable risks, customer acceptability or environmental impact). The coarse screening process also helped rationalise some options from the unconstrained list that were very similar in nature to create an integrated option.

Table 13-1: Coarse screening assessment criteria

Assessment Category	Coarse Screening Assessment Criteria
Feasibility and Risk	• Political acceptability and customer acceptability
Engineering	• Engineering complexity and technological risks
Performance	• Likely scale of supply benefit relative to the supply deficiency • Resilience benefits
Operational	• Compliance risks
Environmental and Social	• Risks to international and national designated sites • HRA and WFD compliance risks • SEA considerations • Planning risks including landscape, recreation and heritage • Socio-economic risks

Where unconstrained options were assessed as having an over-riding constraint or performed very poorly against the majority of criteria, they were rejected and not taken forward to the fine screening stage (Stage 2). Those options rejected at this stage were recorded in an option rejection register where the rationale for rejection was clearly set out.

13.2.4 Stage 2: Feasible options fine screening assessment

Stage 2 involved the fine screening assessment. **Table 13-2** sets out the multiple criteria adopted for the fine screening assessment of those options taken forward for assessment from the coarse screening stage. The criteria included explicit linkages to the statutory SEA, HRA and WFD assessment processes, ensuring that the screening process took account of the environmental screening of the options carried out as part of the statutory assessment process. For each criteria, options were assessed against a five-point grading scale: from 0 (positive/beneficial effect) through to 4 (major adverse/ high risk). The graded scales were defined for each criterion to ensure consistent assessment across all of the options.

Table 13-2: Feasible Options Fine Screening Criteria and Assessment Scale

Fine Screening Criteria
Political acceptability
Customer acceptability/affordability
Engineering Complexity
Indicative Cost/ Benefit (using indicative cost and benefit values £ per Ml)
Flexibility
Benefit (Deployable Output/Volume Saved)
Resilience
Operational and compliance Risks
Water Framework Directive (WFD) risks
Habitats Regulations Assessment (HRA) risks
International and National Designated Conservation Sites
Recreational
Archaeological and Cultural Heritage
Flood risk
International or national designated landscapes (AONBs, National Parks)
Carbon footprint
Risk of spreading invasive species

Assessment Scale
0- Positive/Beneficial
1- Neutral/Negligible Risk
2- Low Risk
3- Medium Risk
4- High Risk

13.2.5 Stage 3: Assessment of option risks and benefits

At Stage 3, the options taken forward from Stage 2 were assessed in greater detail against the fine screening criteria and subject to an evaluation of the risks, costs and benefits. The "best performing" options were taken forward to the Constrained List for more detailed costing and further development of the option. In deciding which options should be taken through to the final stage of assessment (Stage 4), the following factors were taken into consideration:

- The likely scale of the supply-demand deficit over the planning period
- Feedback from the Environment Agency
- The level of uncertainty and risk associated with the available options
- The range of different option types to ensure an appropriate mix of alternative options
- Those options identified as mutually exclusive or having a dependency on other options.
- The performance of the option against the screening criteria.
- Whether the fine screening assessment indicated any "showstoppers" which would preclude the option from being promoted.

13.2.6 Stage 4: Finalisation of Constrained Options

Stage 4 was informed by the outcome of the Stage 3 assessment and discussions across relevant teams in Bristol Water and feedback on options from the Environment Agency. This resulted in a further number of options being screened out to produce the final constrained option list.

13.3 Option Appraisal Findings

In total, 148 separate options were included in the unconstrained option list:

- **Customer Demand Management Options** (to reduce overall customer demand and promote water efficiency): 45 options.
- **Distribution Options** (to reduce leakage and enhance intra-zonal transfers within the distribution network): 24 options.
- **Production Options** (to increase deployable output by improvements at existing Water Treatment Works (WTW) and/or reduce WTW or raw water losses): 26 options.
- **Resource Options** (develop new sources or enhance existing sources): 53 options.

The options are presented in **Appendix H**, highlighting those options that progressed to the various appraisal stages (the green boxes in **Appendix H** indicate those options progressed to the next stage; red boxes indicates those options rejected at that stage). The options have been divided into customer demand, production, distribution and resource options.

Resource options included consideration of several third party water sources and licence trading as set out in **Appendix H**, as well as a number of water trading options between Bristol Water and neighbouring water companies (both imports and changes to our existing exports).

For the **distribution management options**, the initial screening activities (Stages 1 to 3) informed consideration of options to address leakage prior to the development of options through our SELL modelling and assessment. For this final plan, we further reviewed our leakage reduction policy in light of updated SELL information and the strong feedback from many of our customers, regulators and stakeholders that we should reduce leakage beyond our current assessment of SELL. As a result, we have revised our baseline leakage reduction policy (see Section 7) and, as a consequence, revised the leakage options to be considered in the programme appraisal process to Options D21.01 (revised), D21.02 (revised) and D23 (see **Table 13-3**). The initial ALC leakage reduction options and the pressure management options included in the Constrained List of the draft WRMP19 are now included as part of our baseline leakage reduction activities to reduce total leakage to 39.33 Ml/d by 2024/25 (rather than the 43.0 Ml/d baseline position for the draft plan).

Final constrained options

The outcome of the option screening process for the draft WRMP19 was a final constrained list of 20 options (**Table 13-3**) that were then developed in further detail, in particular to refine the costs and benefits to water supply, assessment of resilience benefits and appraisal of environmental performance (including carbon). The final constrained list covers a broad mix of options across the four main option types: from catchment management measures to increasing household metering; from rainwater harvesting at new developments to the construction of new reservoir; and from water efficiency promotion to addressing production constraints at water treatment works. Further details about these options are presented in **Appendix H**. As discussed in Section 6, following ongoing dialogue with Wessex Water since publication of the draft WRMP19, we have now agreed a reduction to our bulk supply export agreement in dry weather from 2024/25 from 11.37 Ml/d to 4.4 Ml/d as part of our baseline supply forecast (see Section 6). Consequently, option R32 (to reduce the Wessex Water bulk supply) is no longer included in the final constrained list of options for this WRMP19.

Table 13-3: Final constrained options list

Option ID	Option	Option Type
C08	Selective metering of domestic customers based on (a) high consumption e.g. sprinkler use and/or (b) zones of high demand	Customer Demand
C12	Enhanced promotion of free meter option to unmeasured households beyond the promotion assumed in baseline demand forecast	Customer Demand
C20	Installation of rainwater harvesting in new build households and non-households	Customer Demand
C26-01	Promotion of Water Efficiency to customers- Enhanced water efficiency communications campaign (different messages for different seasons*). Over and above our baseline water efficiency programme assumed in the baseline demand forecast*	Customer Demand
C26-02	Promotion of water efficiency to customers- Education programme on water efficiency on different key stages (primary, secondary, further and higher education). O*ver and above our baseline water efficiency programme assumed in the baseline demand forecast*	Customer Demand
C26-03	Promotion of water efficiency to customers- Household water efficiency devices installation programme plus selective water saving devices. *Over and above our baseline water efficiency programme assumed in the baseline demand forecast*	Customer Demand
D21.01	Active Leakage Control (ALC): enhanced leak detection and repair activities beyond our baseline leakage policy to reduce leakage to 36.5 Ml/d over the years 2020/21 -2024/25 (2.83Ml/d).	Distribution
D21.02	Active Leakage Control (ALC): enhanced leak detection and repair activities to reduce leakage from 36.5 to 35.0 (0.5 in 2029/30 and 1Ml/d in 2034/35).	Distribution
D23	Asset Renewal: specific targeted water mains asset renewal programme beyond our baseline asset renewal programme included in our baseline leakage policy to maintain leakage at 43 Ml/d as assumed in the baseline demand forecast	Distribution
P01.01	Increase performance of P01-01R WTW to increase deployable output to near licensed volume	Production
P01.02	Increase performance of P01-02R WTW to increase deployable output to near licensed volume	Production
P06	Catchment Management of the Mendip Lakes (P39R, P42R and P10R) to manage outage risk from algal blooms	Production
P08	P08R WTW (increased production)	Production
P10	P10R WTW (increased production)	Production
P20	Reduced leakage from raw water mains (enhanced leakage detection / raw mains repairs/replacement)	Production
R08.02	New water sources within Bristol Water area: R08-02R	Resource

Option ID	Option	Option Type
R08.03	New water sources within Bristol Water area: R08-03R	Resource
R11.01	P10R Reservoir – standard design	Resource
R23.01	Purchase water from other water companies	Resource
R24	Bring R24R source back into supply	Resource

Additionally, in line with national water resources planning guidance on including Drought Plan options in the development of the WRMP, our Drought Plan 2018 options were also considered in developing our WRMP as part of the overall suite of options to maintain a resilient water supply to our customers. These options comprise:

- Appeals to customers for restraint in water consumption.
- Enhanced leakage management.
- Temporary Use Ban (TUB).
- Non Essential Use Ban (NEUB) drought order.
- Emergency Drought Order.
- Drought permit to reduce the compensation flow release from P42R Reservoir.
- Drought permit to reduce the compensation flow release from P39R Reservoir.
- Drought permit to reduce the prescribed flow at P10R Reservoir.
- Bring R24R source back into supply.

It should be noted that the Drought Plan option to bring the R24R source back into supply is mutually exclusive with the WRMP option R24 to achieve the same outcome.

13.4 Constrained options: costs and deployable output/demand saving benefits

The constrained options were developed further in terms of the design assumptions and, where applicable, outline engineering detail so as to inform the refinement of the deployable output or demand saving benefits of each option and to develop the capital and operating costs. The costs and benefits of each of the options were used to calculate the discounted Average Incremental Costs (AIC) in line with the Water Resources Planning Guideline.

Table 13-4 sets out the deployable output benefit (Ml/d) or demand saving (Ml/d) along with the AIC for each of the constrained options. **Table 13-4** shows that:

- The first tranche of further leakage reduction through active leakage control (Option D21.01) is the least cost option based on AIC values.
- Due to the revisions made to our baseline leakage reduction policy since the draft WRMP19, the updated active leakage control option D21.02 is no longer one of the lowest cost options as it was in the draft plan (as explained above, the cheapest leakage options in the draft plan are now part of our baseline leakage reduction programme and the revised options in the Constrained List are incrementally more expensive).
- Leakage control through replacement and renewal of trunk mains (D23) is one of the more expensive options.
- Reduced losses (leakage) from raw water mains (P20) and actions to increase production at P08R WTW (P08) are of a similar unit cost, followed by bringing the R24R source back

into use (R24). These options are more cost-effective than the lowest cost customer metering options (C08 and C12)

- Addressing production constraints at P01-02R WTW (P01-02) and the water efficiency education programme (C26-02) are the next most cost-effective options, followed by the purchase of bulk supplies from other water companies (R23-01) and increasing the performance of P01-01R WTW (P01-01).
- The remaining constrained options are considerably more expensive than the above options, including enhanced water efficiency measures, developing new water sources and installation of rainwater harvesting in new developments.

Table 13-4: Constrained options: Average Incremental Costs (£/Ml)

Option ID	Option	Benefit (Ml/d)	AIC (£/Ml)
C08	Selective metering of domestic customers based on (a) high consumption e.g. sprinkler use and/or (b) zones of high demand	0.57	95.74
C12	Enhanced promotion of free meter option to unmeasured households	0.572	95.41
C20	Installation of rainwater harvesting in new build households and non-households	0.029	1409.72
C26-01	Promotion of Water Efficiency to customers- Enhanced water efficiency communications campaign (different messages for different seasons).	0.08	3424.66
C26-02	Promotion of Water Efficiency to customers- Education programme on water efficiency on different key stages (primary, secondary, further and higher education).	0.08	342.47
C26-03	Promotion of Water Efficiency to customers- Household water efficiency devices installation programme plus selective water saving devices	0.266	191.30
D21.01	Active Leakage Control (ALC): enhanced leak detection and repair activities (first phase reduction)	0.84 to 2.83	16.3
D21.02	Active Leakage Control (ALC): enhanced leak detection and repair activities (second phase reduction)	0.5 -1.5	57.92
D23	Asset Renewal: specific targeted water mains asset renewal programme beyond our baseline asset renewal programme	0.5	7259.21
P01-01	Increase performance of P01-01R WTW to increase deployable output to near licensed volume	1.7	192.50
P01-02	Increase performance of P01-02R WTW to increase deployable output to near licensed volume	2.64	67.64
P06	Catchment Management of the Mendip Lakes (P39R, P42R and P10R) to manage outage risk from algal blooms	0.394	347.68
P08	P08R WTW (increased production)	2	22.09
P10	P10R WTW (increased production)	4	142.24
P20	Reduced leakage from raw water mains (enhanced leakage detection / raw mains repairs/replacement)	5.5	24.27
R08-02	New water sources within Bristol Water area: R08-02R	1.4	401.89
R08-03	New water sources within Bristol Water area: R08-03R	1.1	144.14

Option ID	Option	Benefit (Ml/d)	AIC (£/Ml)
R11	P10R Reservoir – standard design	16	183.14
R23-01	Purchase water from other water companies	10	102.42
R24	Bring R24R source back into supply	2.4	42.06

13.5 Constrained options: Resilience Assessment

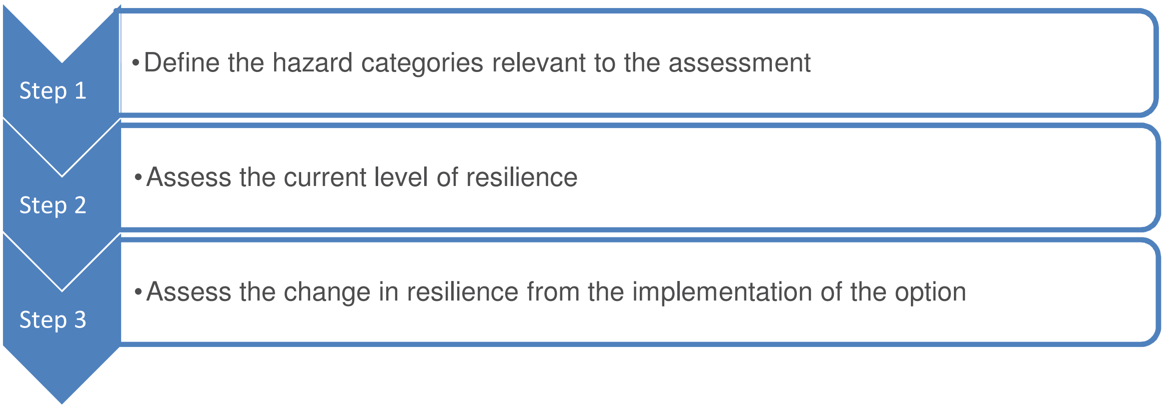
13.5.1 Methodology overview

We have carried out an assessment of the potential resilience benefits that each constrained option may bring to the water supply system. Resilience can be defined, in the context of water resource planning, as “the ability of a source/asset and/or water supply system to withstand and respond to a disruptive event or change”. The assessment process involved:

- An assessment of the current level of resilience against a range of specified possible hazards to water supply reliability.
- Assessing the change in resilience to Bristol Water’s supply system from implementing each of the constrained list options.

The overarching assessment approach was principally based on the UKWIR (2013) resilience assessment methodology. The overall purpose of the assessment was to determine the extent to which each option may provide a resilience benefit to the water supply system (if any). The assessment was undertaken in three key stages as shown in **Figure 13-3** and covered all types of options: Customer Demand, Distribution, Production and Resource options. The assessment was related to specific water supply assets or sites (Production and Resource schemes) and/or to the overall water supply network (Customer Demand and Distribution Schemes). Lessons learned from the cold weather in March 2018 have been taken into account in carrying out these assessments.

Figure 13-3: Three-stage resilience assessment process



A resilience rating was assessed for each identified hazard for the relevant source(s), asset(s) and/or water supply system, as appropriate, in consultation with our operational and planning staff. For each hazard, resilience was assessed using a scoring system scaled from zero to +4 (see **Table 13-5**) for each of the UKWIR components of resilience: resistance, reliability, redundancy, response and recovery. The scores were summed and multiplied by the assessed effects on levels of service (rated on a scale from 1 to 3) to produce an overall resilience rating.

Table 13-5: Resilience component categories (UKWIR, 2013)

Category	Definition	Score
Resistance	Ability to prevent damage or disruption by resisting the hazard	Score 0 (High resilience) to 4 (Poor resilience)
Reliability	Scheme is inherently designed to operate under a range of conditions and mitigate damage or loss from an event	
Redundancy	Capacity, availability of backup installations or spare capacity	
Response & Recovery	Being able to enable a fast and effective response and recovery from disruptive events	
Levels of Service	Ability of the water company to be able to provide uninterrupted supply of wholesome drinking water to customers	Score 1 (Low impact) to 3 (High impact)

The final step was the assessment of the potential change in resilience that may arise from implementation of each of the constrained options using the same scoring approach as adopted for the current level of resilience so as to produce a modified resilience score. The net change in resilience (i.e. current resilience score – modified resilience score) was then calculated and this net change value was used as the resilience "metric".

Table 13-6 summarises the findings of the resilience assessment indicating the net change in the resilience score arising from implementation of each option. These resilience benefit scores were included within our programme investment appraisal model but were not used due to the small-scale supply deficit forecast which did not require the use of a multi-criteria modelling approach. However, the resilience assessment has helped to inform decision-making, highlighting those options that provide wider non-drought resilience benefits.

The assessment showed that:

- Customer demand management and leakage reduction measures provide a lower level of resilience benefit due to the relatively low level of water savings achieved relative to the total customer demand for water. The key benefit is a reduction in demand during period of peak demand and/or water scarcity and therefore providing an increase to the resilience of the supply network. This is important in both hot, dry weather peak demand and very cold (freeze-thaw) conditions as experienced recently in March 2018 where a high peak in demand arose due to increased bursts, mainly on customer supply pipes.
- Resource management options provide a low to moderate level of resilience benefit depending on the specific nature of the scheme and the volume of additional water supply capacity provided by the option
- Production management options provide the highest level of resilience benefit, reflecting the nature of the investment which will increase the reliability and robustness of the treatment processes and assets.

Table 13-6: Net change in resilience scores for each constrained option

Option ID	Option	Net change in resilience score
C08	Selective metering of domestic customers based on (a) high consumption e.g. sprinkler use and/or (b) zones of high demand	3
C12	Enhanced promotion of free meter option to unmeasured households beyond the promotion assumed in baseline demand forecast	3
C20	Installation of rainwater harvesting in new build households and non-households	0
C26-01	Promotion of Water Efficiency to customers- Enhanced water efficiency communications campaign (different messages for different seasons).	1
C26-02	Promotion of Water Efficiency to customers- Education programme on water efficiency on different key stages (primary, secondary, further and higher education).	1
C26-03	Promotion of Water Efficiency to customers- Household water efficiency devices installation programme plus selective water saving devices	1
D21.01	Active Leakage Control (ALC)	3
D21.02	Active Leakage Control (ALC)	3
D23	Asset Renewal	1
P01-01	Increase performance of P01-01R WTW to increase deployable output to near licensed volume	6
P01-02	Increase performance of P01-02R WTW to increase deployable output to near licensed volume	5
P06	Catchment Management of the Mendip Lakes (P39R, P42R and P10R) to manage outage risk from algal blooms	5
P08	P08R WTW (increased production)	5
P10	P10R WTW (increased production)	6

Option ID	Option	Net change in resilience score
P20	Reduced leakage from raw water mains (enhanced leakage detection / raw mains repairs/replacement)	2
R08-02	New water sources within Bristol Water area: R08-02R	2
R08-03	New water sources within Bristol Water area: R08-03R	2
R11	P10R Reservoir – standard design	5
R23-01	Purchase water from other water companies	4
R24	Bring R24R source back into supply	2

13.6 Constrained options: assessment of environmental and social effects

All of the constrained options were subject to detailed statutory environmental and social assessment:

- Strategic Environmental Assessment (SEA)
- Habitats Regulations Assessment (HRA)
- Water Framework Directive Assessment (WFD)

In addition, a semi-quantitative ecosystems services assessment was carried out for each of the constrained options to provide an alternative insight into the beneficial and adverse effects of the different options on ecosystem services, complementing the statutory environmental assessment processes. The options were also evaluated in light of our customer research evidence on water supply services.

These environmental and social assessments were used to inform the subsequent programme appraisal process and decision-making on the final preferred plan. Further details on the environmental and social appraisal of the constrained options are provided in **Section 14**.

14 Environmental Appraisal

Section Overview

We have formally appraised all of the feasible options presented in **Section 13**. The appraisal was undertaken by external consultants and initially covered a high level assessment for the full set of options; there was then a more detailed assessment for the 20 constrained options set out in **Section 13** against Strategic Environmental Assessment Regulations, Water Framework Directive, Habitats Regulations, International and National Designated Conservation Sites, recreational impacts, archaeological and cultural heritage, flood risk, international and national designated landscapes, carbon costs and risks relating to spreading invasive species.

We also undertook ecosystems services, resilience and customer views assessment and these are also reported in this section. In **Section 15** we bring together the potential options, and the justifications for selection and other attributes, to develop the preferred programme of measures which form the final WRMP.

14.1 Methodology overview

The July 2018 Final Water Resources Planning Guideline (interim update), Defra guiding principles and UKWIR guidance advises that water companies should consider the environmental and social effects (beneficial and adverse) of the options considered for balancing supply and demand, and the effects of the WRMP overall.

We have considered environmental risks from the very outset of the options appraisal process, including statutory environmental requirements (notably WFD, HRA and SEA European Directives as well as key national environmental legislation and protection). As explained in **Section 13**, all of the unconstrained options were assessed in relation to the following environmental criteria:

- Risks to international and national designated sites
- HRA and WFD compliance risks
- SEA considerations
- Planning risks including landscape, recreation and heritage
- Socio-economic risks

At the fine screening stage (see **Section 13**), options were further assessed for their environmental performance in respect of:

- WFD risks
- HRA risks
- International and National Designated Conservation Sites
- Recreational
- Archaeological and Cultural Heritage
- Flood risk
- International or national designated landscapes (AONBs, National Parks)

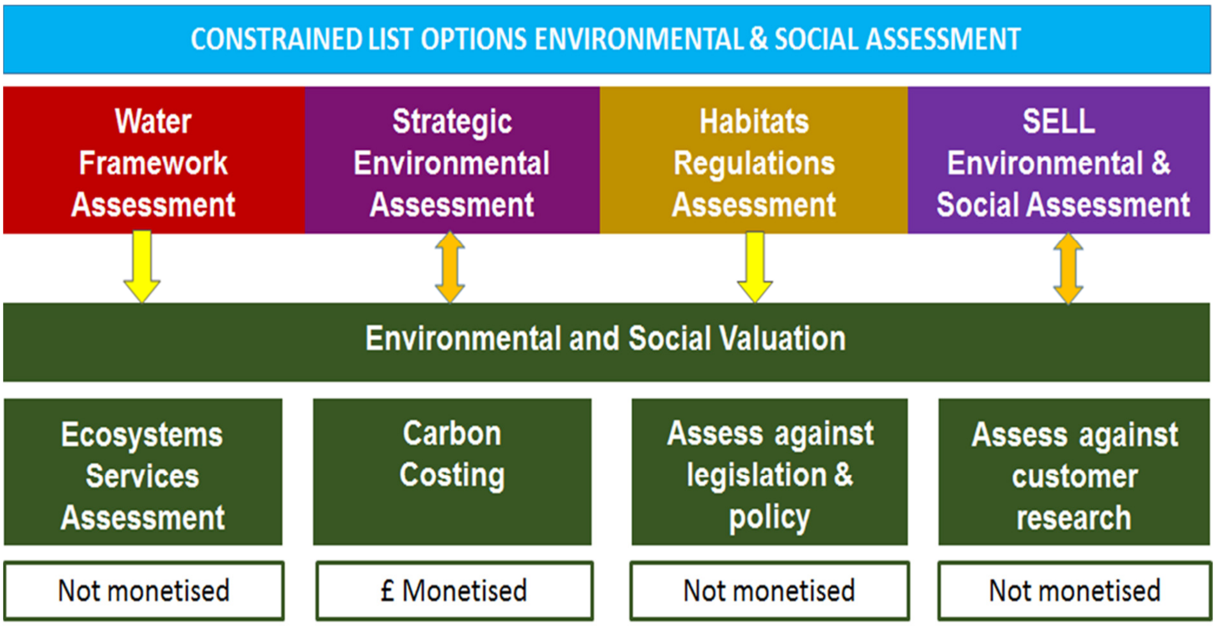
- Carbon footprint
- Risk of spreading invasive species

Through the screening process, several unconstrained and feasible options were rejected due to the potential for significant adverse effects on the environment and/or on socio-economic factors.

For the remaining constrained list options, we adopted an integrated environmental and social assessment approach for the assessment of the constrained options as summarised in **Figure 14-1**. The statutory environmental assessment processes of SEA, HRA and WFD assessment were at the core of the approach, supported by the Sustainable Economic Level of Leakage (SELL) environmental and social assessment and environmental valuation (including carbon valuation, ecosystems services assessment and consideration of customer research evidence).

Where applicable, mitigation measures have been identified to prevent, reduce or offset any identified significant adverse environmental effects of constrained options. These mitigation measures have been taken into account in assessing the residual effects on the environment.

Figure 14-1: Integrated approach to environmental and social assessment and valuation



14.2 Statutory environmental and social assessments

14.2.1 Strategic Environmental Assessment (SEA)

As explained earlier in **Section 4** of this Plan, we have carried out a Strategic Environmental Assessment (SEA) of our WRMP (**Appendix E**). The SEA has been fully integrated with the option appraisal process to inform the selection of the best value options for both our customers and the environment. The SEA Environmental Report (2018), updated in line with the WRMP, presents an assessment of the likely social and environmental effects of the WRMP and identifies ways in which any adverse effects can be avoided, minimised or mitigated and how positive effects can be enhanced.

The results of the SEA assessment are presented in the SEA Environmental Report and summarised in this Section. The SEA Environmental Report (2017) associated with the dWRMP, was included in the public consultation process for the dWRMP.

The assessment methodology was set out in our SEA Scoping Report that was subject to statutory consultation in spring 2017. Following consideration of the responses received, the assessment framework was revised to consist of 12 SEA objectives supported by 53 guide questions. The construction and operational effects of each option has been assessed against all of the SEA objectives (for example, biodiversity, water quality, climate change and landscape objectives).

The assessment approach recognises that many of the options under consideration within the WRMP are likely to be very different in nature in their construction and operational phases, and so effects were considered separately for these two distinct phases.

The following factors were taken into account when identifying and assessing the likely effects of the WRMP options on the SEA objectives:

- The nature of the potential effect (what is expected to happen).
- The timing of the potential effect.
- The potential effect on vulnerable communities, sensitive habitats and/or ecosystems.
- The geographic scale of the potential effect (e.g. local, regional, national).
- The location of the potential effect.
- The duration of the potential effect (e.g. short, medium or long term).

Specific guidance was followed to inform what constitutes a significant effect, a minor effect or a neutral effect for each of the SEA objectives. These 'definitions of significance' helped to ensure a consistent approach to interpreting the significance of effects and assist the reader in understanding the decisions made by our assessors. The findings of the SEA are summarised in **Section 14.3**.

14.2.2 Habitats Regulations Assessment (HRA)

Under Regulation 61 of the Habitats Regulations, any plan or project which is likely to have a significant effect on a European site (either alone or in combination with other plans or projects) and is not directly connected with or necessary for the management of the site, must be subject to an assessment to determine the implications for the site in view of the site's conservation objectives.

Therefore, as the competent authority, Bristol Water is required to undertake a Habitats Regulations Assessment screening exercise to assess the potential effects on European sites (also known as Natura 2000 sites) of implementing our WRMP. European sites include those sites designated as Special Areas of Conservation (SAC) under the EU Habitats Directive, Special

Protection Areas (SPA) under the Birds Directive, and Ramsar sites under the international Ramsar Convention.

The HRA is reported separately from the SEA, in **Appendix F**. The HRA has been used to help inform the SEA, particularly the SEA objectives relating to the potential effects of options and the Plan on biodiversity.

For the HRA, the assessment focused on the resource and production options; customer demand options and the distribution options were 'screened out' from requiring assessment as both option types are designed to reduce water consumption and these types of activities are considered not to have any risk of leading to negative effects any European sites. All of the WRMP resource and distribution options were subject to the HRA Stage 1 screening assessment and the findings are summarised in **Section 14.4**.

14.2.3 Water Framework Directive (WFD) assessment

In line with statutory requirements and following WRMP regulatory guidance, we have carried out a Water Framework Directive (WFD) assessment to assess the potential effects of implementing our Plan on designated WFD water bodies and Protected Areas, in particular to assess whether the Plan may lead to deterioration in the status class of any WFD water body. The WFD assessment is reported separately from the SEA in **Appendix I**. The WFD report has been used to help inform the SEA, particularly the SEA objectives relating to the potential effects of options and the Plan on biodiversity and the water environment.

The WFD assessment was completed for eleven feasible options. The assessment for each option comprised two stages, a 'Level 1' screening, followed by a more detailed 'Level 2' assessment for those water bodies that may be subject to medium or high impacts. The results of both levels of assessment are then combined to create a final impact assessment for all options. The key findings from the WFD assessment are summarised in **Section 14.5.**

14.2.4 Carbon assessment

In line with the requirement set out in the Water Resources Management Plan (England) Direction 2017, carbon emissions and carbon costs for each constrained option were calculated in accordance with national government and regulatory guidance:

- HM Treasury Green Book and carbon costing guidance
- Department of Energy and Climate Change (DECC) Supplementary Appraisal Guidance for Valuing Greenhouse Gas Emissions and Energy Use
- UK Government Inter-departmental Analysts' Group (IAG) spreadsheet tool for valuing changes in greenhouse gas emissions
- Ofwat guidance on carbon reporting and costing
- UKWIR guidance on assessing embodied and operational carbon, including the latest available UKWIR carbon emissions workbook
- Environment Agency supplementary WRMP19 guidance on environmental valuation

14.2.5 Environmental valuation and ecosystem services assessment

The Environment Agency's guidance (2016) on environmental valuation for water resources planning sets out expectations on the application of environmental valuation for WRMP19 around four key principles:

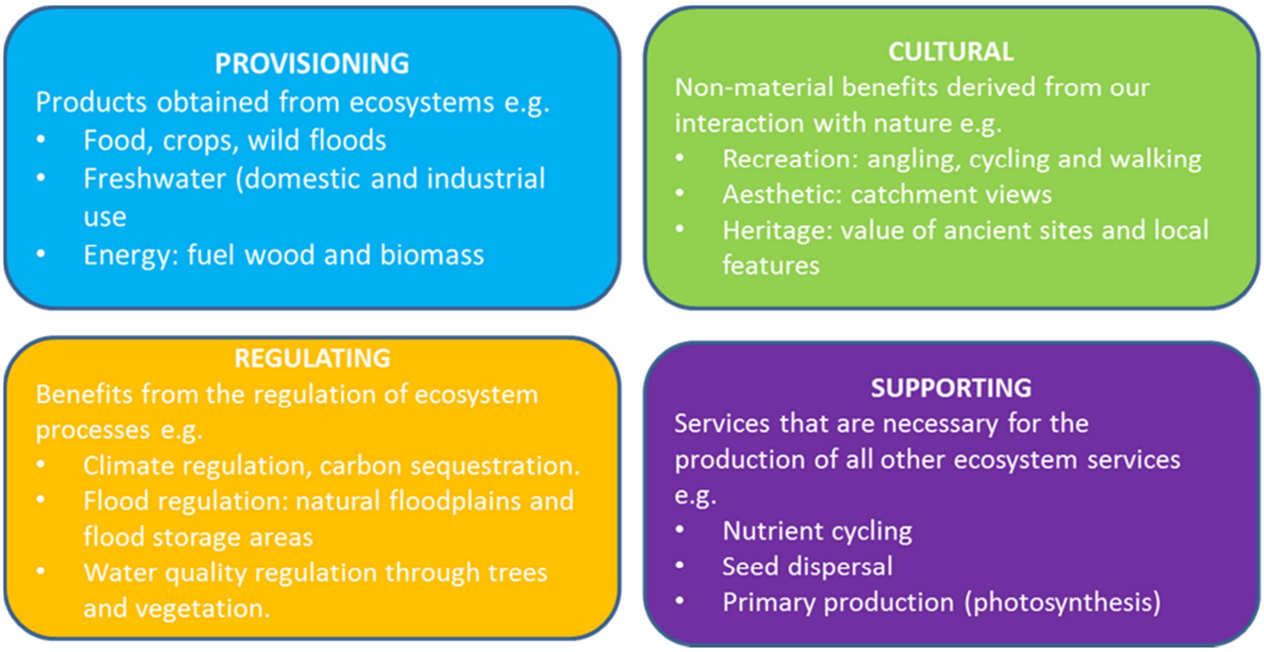
- Methods should be proportionate to scale of water resource problems faced.
- Consider use of ecosystem services approach to environmental valuation.
- Use best available evidence and/or develop new valuation evidence.
- Adopt a transparent process to assessing environmental effects and valuation.

We have followed this guidance in developing our approach to environmental and social valuation. As shown in **Figure 14-1,** we have only monetised carbon effects and have adopted a semi-quantitative assessment approach for other environmental and social effects. We have followed this approach due to the current uncertainties in the use of economic valuation surveys and willingness to pay evidence for WRMP options assessment. Our approach comprises four key assessments as described below.

Ecosystems Services Assessment

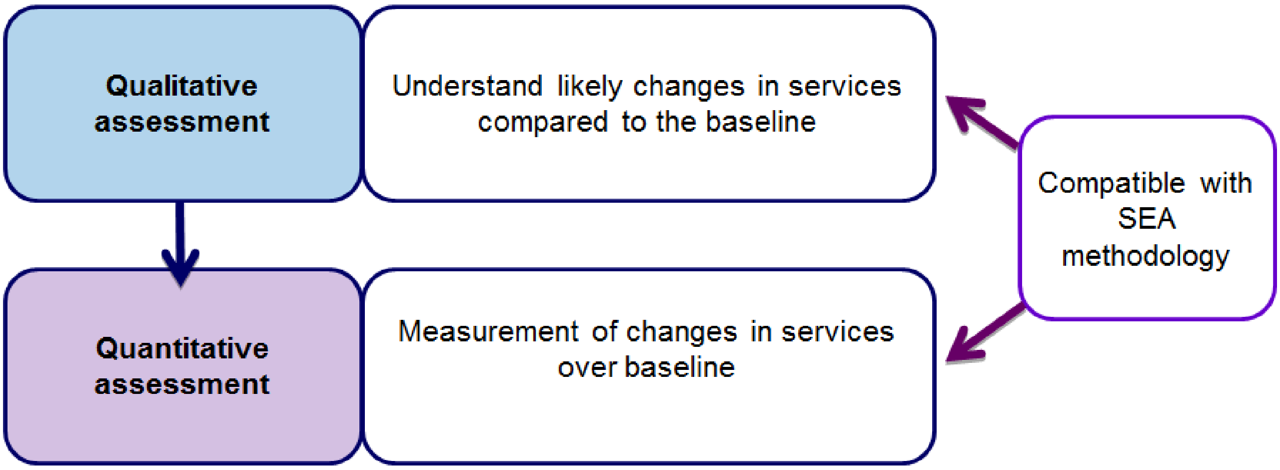
In line with Defra's guiding principles and the EA guidance, each constrained option was assessed using the ecosystems services assessment approach. **Figure 14-2** summarises the four principal ecosystem services categories that have been included in the assessment.

Figure 14-2: Ecosystems Services Categories



As identified in the Water Resources Planning Guideline, using an ecosystem services framework for options appraisal helped to ensure that a wide range of potential impacts were considered. The approach identified the likely scale of the expected impacts (ensuring a proportionate level of effort) and that the relevant beneficiaries or dis-beneficiaries have been considered. **Figure 14-3** provides a simplified summary of the approach. The key findings of the assessment are presented in **Section 14-7** and **Appendix J**.

Figure 14-3: Ecosystems Services Approach (simplified)



Assessment against environmental policy

Each option was tested against the key relevant legislative aims and policy objectives that were identified in the SEA review of policies and legislation. This comprised a qualitative assessment showing the extent to which options are consistent with the legislative aims and policy objectives against a graded scale:

- Positively supports the aim/objective (+++)
- Broadly supports the aim/objective (++)
- Partially supports the aim/objective (+)
- Neutral effect (N)
- May hinder the aim/objective (-)
- Broadly hinders the aim/objective (- -)
- Major hindrance to the aim/objective (- - -)

Assessment against relevant customer research evidence

Relevant evidence from our customer research activities was used to inform this assessment. Each option was tested against the relevant customer evidence provided by our research. A qualitative assessment was adopted rather than a quantitative assessment as the data acquired through customer research were not explicitly collected or designed for environmental and social valuation purposes. The qualitative assessment used a graded scale as follows:

- Option likely to be positively supported by customers (+++)

- Option broadly in line with customer views (++)
- Option partially in line with customer views (+)
- Neutral customer views likely (N)
- Option partially not in line with customer views (-)
- Option broadly contrary to customer views (- -)
- Option likely to be substantially contrary to customer views (- - -)

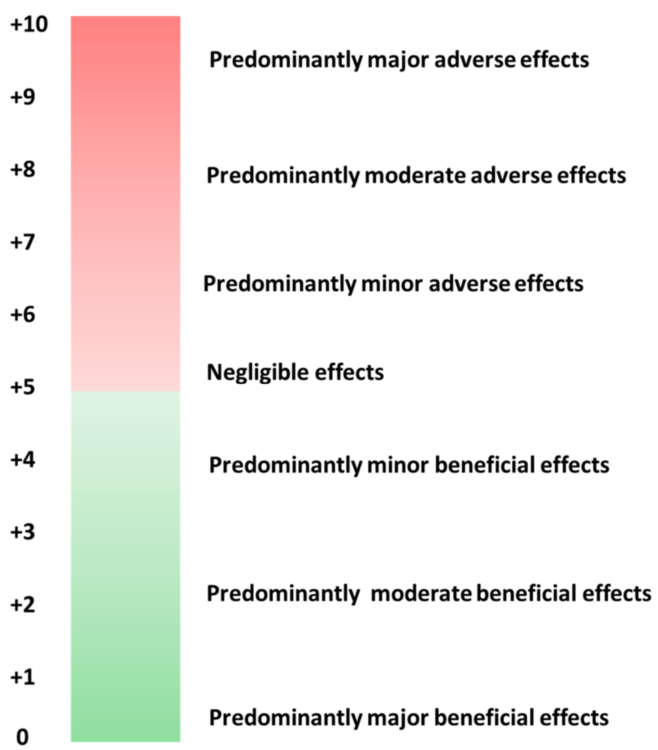
14.2.6 Environmental and social metric

In order to provide the programme investment appraisal model with information about the environmental and social performance of each WRMP option in the Constrained List (and Drought Plan options), an environmental and social metric was developed. The metric is based on a graded scale from zero to ten (**Figure 14-4**), with the assessment process keeping beneficial and adverse effects separate in line with SEA best practice.

The metrics were derived directly from consideration of the findings of the SEA, HRA and WFD assessments. If the HRA indicated that an option would lead to Likely Significant Effects on a European site, and/or lead to permanent deterioration of WFD status between status classes, the adverse effects grading would automatically be assigned at a minimum of -9 to reflect the fact that such an option would be unlikely to be acceptable and therefore carry a high "penalty" grading.

In order to avoid "double-counting" of the carbon effects, the environmental metric for the investment appraisal model excludes the carbon externalities as these have been included as monetary values in the programme investment appraisal model.

Figure 14-4: Graded scale for Environmental and Social Metric



14.3 Strategic Environmental Assessment

14.3.1 Options assessment

The Environmental Report (**Appendix E**) includes the detailed findings of the SEA. The SEA assessment concluded that:

- The **customer demand** options have few adverse environmental and social effects and would bring some minor beneficial effects. The minor adverse effects centre on the effects on climate change and resource use objectives in respect of the metering and rainwater harvesting options (use of materials to manufacture meters and equipment). Minor beneficial effects would be expected to be realised in relation to the water quantity and water resource objectives.
- Some of the **production options** have minor to significant adverse effects in respect of climate change and resource use objectives (reflecting the need for materials to upgrade water treatment works and operate the upgraded processes). Some minor adverse effects may arise for some options in relation to temporary construction impacts on the local community. Minor beneficial effects are identified for some of the options, including in relation to economic and social well-being and water resources objectives. Additionally, the catchment management scheme for the Mendip Lakes reservoir catchments (P06) has minor beneficial effects for soils, geology and biodiversity objectives.
- The assessed effects relating to **resource options** vary dependent on the nature of the option and its geographical setting in relation to environmental and social receptors. The resource options give rise to greater adverse effects compared to the other option types, ranging from neutral to significant adverse effects for some objectives for some options. Equally, there is a broad range of identified beneficial effects. Some options bring both significant adverse effects and significant beneficial effects.
- The distribution options are generally assessed as having beneficial effects, but some adverse effects are identified in relation to climate change, waste and resource use and economic and social well-being reflecting the disruption that street works can cause to local communities and the energy and resources involved in leakage control activities.

14.3.2 Environmental and Social Metrics

Based on the SEA findings for each of the Constrained Options, environmental and social metrics were assessed for each option in accordance with the methodology described above in **Section 14.1**.

Table 14-1 sets out the metrics for each option (including the Drought Plan options) for both construction and operational effects; these metrics were incorporated into our investment programme appraisal model to provide an indication of the environmental performance of each option. The metrics provide a very high level summary of the environmental assessment findings described above; importantly, these metrics are **not** a substitute for the more detailed SEA, HRA and WFD appraisal processes - the WRMP programme outputs from the investment appraisal model were subject to detailed SEA, HRA and WFD assessment to help final decision-making on the preferred plan. The metrics were not eventually used within the model due to the small scale of the deficit that has emerged from our supply-demand assessments but the approach has been developed for future use, if required.

Table 14-1: Environmental and Social Metrics for the Constrained Options and Drought Plan Options

Option Reference	Option Type	Option Name	Construction Effects		Operational Effects	
			Beneficial	**Adverse**	**Beneficial**	**Adverse**
C08	Customer Demand	Selective metering of domestic customers based on (a) high consumption e.g. sprinkler use and/or (b) zones of high demand	5	4	4	5
C12	Customer Demand	Enhanced promotion of free water meters to unmeasured households beyond the promotion assumed in baseline demand forecast	5	4	4	5
C20	Customer Demand	Installation of rainwater harvesting in new build households	5	4	4	5
C26-01	Customer Demand	Enhanced water efficiency communications campaign (different messages for different seasons)	5	5	4	5
C26-02	Customer Demand	Water efficiency on different key stages (primary, secondary, further and higher education)	5	5	4	5
C26-03	Customer Demand	Household water efficiency devices installation programme	5	5	4	5
D21.01	Distribution	Active Leakage Control (ALC): enhanced leak detection and repair activities beyond our baseline leakage policy to reduce leakage to 36.5 Ml/d over the years 2020/21 -2024/25 (2.83Ml/d).	5	6	3	5
D21.02	Distribution	Active Leakage Control (ALC): enhanced leak detection and repair activities to reduce leakage from 36.5 to 35.0 (0.5 in 2029/30 and 1Ml/d in 2034/35)	5	6	3	5
D23	Distribution	Asset Renewal: replacement and renewal of trunk mains	3	8	4	5
P01-01	Production	Increase performance of existing sources (P01-01R) to increase deployable output to near licensed volume	4	6	3	6

Option Reference	Option Type	Option Name	Construction Effects		Operational Effects	
			Beneficial	**Adverse**	**Beneficial**	**Adverse**
P01-02	Production	Increase performance of existing sources (P01-02R) to increase deployable output to near licensed volume	4	6	3	6
P06	Production	Catchment Management of the Mendip Lakes (P39R, P42R and P10R) to manage outage risk from algal blooms	5	6	3	5
P08	Production	P08R WTW (increased production)	4	6	3	6
P10	Production	P10R WTW (increased production)	2	9	3	6
P20	Production	Reduced leakage from raw water mains (enhanced leakage detection / raw mains repairs/replacement)	3	8	3	5
R08-02	Resource	New water sources within Bristol Water CAMS area for the location R08-02R	2	9	4	7
R08-03	Resource	New water sources within Bristol Water CAMS area for the location R08-03R	4	10	4	6
R11	Resource	P10R Reservoir Standard WRMP14 design	2	10	0	7
R23-01	Resource	Purchase Water from Third Parties from Water Companies	2	10	2	6
R24	Resource	Bring R24R source back into supply	5	10	3	6
N/A	Drought Plan	Appeals for restraint	5	5	4	5
N/A	Drought Plan	Enhanced leakage management	5	5	4	5
N/A	Drought Plan	Temporary Use Ban (TUB)	5	5	4	6
N/A	Drought Plan	Drought Order to prohibit prescribed non-essential water uses (NEUB)	5	5	4	7
N/A	Drought Plan	Emergency Drought Order	5	5	4	9
N/A	Drought Plan	R24R and R24Ra (Well Head)	5	10	3	6
N/A	Drought Plan	Reduction in compensation flow release from P42R Reservoir	5	5	4	7
N/A	Drought Plan	Reduction in compensation flow release from P39R Reservoir	5	5	4	7
N/A	Drought Plan	Reduction of prescribed flow at P10R Reservoir	5	5	4	6

14.4 Habitats Regulation Assessment (HRA)

The HRA report (**Appendix F**) includes the detailed findings of the assessments on production and resource options.

The assessment concluded that none of the options included in our WRMP19 would have a likely significant effect on any European site, either alone or in combination with other options, programmes or plans.

As part of the baseline supply forecast (Section 6), we have included an agreed reduction with Wessex Water to our bulk export to their Bath supply area. Wessex Water has confirmed that this reduction will be offset by use of existing licensed water sources and demand management activities. As a consequence, this reduction to the bulk export will not have any likely significant effects on any European site.

The conclusion of the HRA of the WRMP is that the plan will have **no likely significant effects on any European site, either alone or in combination with any other projects or plans**. These HRA findings were taken into account in making decisions on the preferred programme for the WRMP.

14.5 Water Framework Directive Assessment

Table 14-2 summarises the findings of the WFD assessment for the resource and production options. This shows that these options generally have a minimal to minor level of impact on WFD water bodies.

Table 14-2: Summary of combined WFD results

	No of option–water body combinations	No of water bodies	No of options
Total	36	24	11
High level of impact	2	1	2
Medium level of impact	4	4	3
Minor level of impact	21	19	6
No or minimal impact	9	6	7

Note that a water body may have varying levels of impact from different options, and an option may have differing levels of impact on different water bodies. This means that some water bodies and options are counted more than once in the values in this table.

The WFD assessment concluded that further assessment work would be required for those options with a medium or a high level of impact, including:

- R08-02: New water sources for the R08-02R.
- R11: P10R Reservoir.
- R23-01: Purchase water from third parties.
- P08: P08R WTW.
- P10: P10R WTW.

These WFD assessment findings were taken into account in making decisions on the preferred programme for the WRMP.

14.6 Carbon Assessment

Embodied and operational carbon emissions were calculated in tonnes of CO_2 equivalent (CO_2et) for each option in accordance with our company carbon emission methodology, which adopts the relevant water industry and government guidance. The carbon emission values were converted to carbon costs (in £) in accordance with the UK government carbon calculation methods. For the distribution options, carbon costs were included in the Sustainable Economic Level of Leakage (SELL) model in accordance with regulatory guidance. **Table 14-3** provides a summary of the carbon emission (tonnes CO_2et) and carbon cost values (£) for each constrained option.

Table 14-3: Constrained options: carbon emissions and carbon costs

Option ID	Option	Embodied Carbon (tonnes CO_2e)	Embodied Carbon Costs (£)	Operational Carbon (tonnes CO_2e)	Operational Carbon Costs (£)
C08	Selective metering of domestic customers based on (a) high consumption e.g. sprinkler use and/or (b) zones of high demand	138 (over 5 years)	1,700.35	Negligible net change	N/a
C12	Enhanced promotion of free meter option to unmeasured households beyond the promotion assumed in baseline demand forecast	138 (over 5 years)	1,700.35	Negligible net change	N/a
C20	Installation of rainwater harvesting in new build households and non-households	225 (over 5 years)	2,988.9	None	N/a
C26-01	Promotion of Water Efficiency to customers- Enhanced water efficiency communications campaign (different messages for different seasons).	No embodied carbon	0.000	0.1	6.642
C26-02	Promotion of Water Efficiency to customers- Education programme on water efficiency on different key stages (primary, secondary, further and higher education).	No embodied carbon	0.000	0.8	53.136
C26-03	Promotion of Water Efficiency to customers- Household water efficiency devices installation programme plus selective water saving devices	5.25	69.7	3.5	232.470
D21.01	Active Leakage Control (ALC): continuation of the current leak detection find and fix policy	134 per year over 5 years	14,700.0	Negligible net changes	N/a
D21.02	Active Leakage Control (ALC): continuation of the current leak detection find and fix policy	71 per year over 5 years	3,400.0	Negligible net changes	N/a
D23	Asset Renewal: replacement and renewal of trunk mains	No embodied carbon	0	Beneficial scheme (carbon saving 170)	-11220

Option ID	Option	Embodied Carbon (tonnes CO_2e)	Embodied Carbon Costs (£)	Operational Carbon (tonnes CO_2e)	Operational Carbon Costs (£)
P01.01	Increase performance of P01-01R WTW to increase deployable output to near licensed volume	158.2 per year during construction	10,507.6	485	32,213.660
P01.02	Increase performance of P01-02R WTW to increase deployable output to near licensed volume	158.2 per year during construction	10,381.4	329.5	21,885.363
P06	Catchment Management of the Mendip Lakes (P39R, P42R and P10R) to manage outage risk from algal blooms	371 per year	24,641.8	2.4	159.408
P08	P08R WTW (increased production)	69	2,291.5	6.9	458.297
P10	P10R WTW (increased production)	58,533	1,943,878.5	4.1	272.322
P20	Reduced leakage from raw water mains (enhanced leakage detection / raw mains repairs/replacement)	1,236 over 5 years	16,419.0	Negligible net changes	
R08-02	New water sources within Bristol Water area: R08-02R	4,560	151,437.4	1,148	76,250.064
R08-03	New water sources within Bristol Water area: R08-03R	3,911	129,884.1	66	4,383.714
R11	P10R Reservoir – standard design	87,000	1,926,177.6	Beneficial scheme (carbon saving 94)	-6,243.472
R23-01	Purchase water from other water companies	14,881	329,464.9	664	42,774.426
R24	Bring R24R source back into supply	1,583	105,142.7	108	7,173.351

*scheme may result in minor additional vehicle movements above the baseline but deemed insignificant.

These carbon costs were included in the option appraisal model alongside the capital and operating costs for each option.

14.7 Ecosystem Services Assessment

The outcome of the Ecosystem Services assessment is presented in **Appendix J**. The assessment focused on the effects of each option (adverse and/or beneficial) on the different types of services provided by the environment. The findings show that most of the options have either a neutral or beneficial effect on the range of ecosystem services considered, with only a small number of adverse effects identified, notably impacts on climate regulation associated with additional carbon consumption from most of the options.

14.8 Customer Preference in relation to WRMP Options

As detailed in **Section 3.1** we have undertaken a wide range of research on customers views and preferences in the development of this WRMP, which includes economic valuation data (quantitative) and qualitative data. Full details and outcomes of the research can be found in **Appendix C** and **D.** In order to ensure our options are consistent with customer preferences we have assessed each option against the outcomes of customer research to date. The key data used in this assessment includes:

- Economic valuation data
- Non valuation research findings.

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The outcome of this assessment is presented below in **Table 14-4**. The assessment indicates those options likely to be positively supported by customers (+++) through to those options likely to be substantially contrary to customer views (- - -), as shown in **Figure 14-5**.

Figure 14-5: Assessment framework for customer research

Key	Assessment
	Option not included in survey
---	Option likely to be substantially contrary to customer views
--	Option broadly contrary to customer views
-	Option partially not in line with customer views
N	Neutral customer views likely
+	Option partially in line with customer views
++	Option broadly in line with customer views
+++	Option likely to be positively supported by customers

Table 14-4: Customer preferences on new water resource options assessed against our WRMP19 options

Option Number	Option description	Preference for Option	Economic Valuation	Non-valuation research findings
C26-01	Promotion of Water Efficiency to customers- Enhanced water efficiency communications campaign (different messages for different seasons)	+++	Both household and non-household customers expressed a strong preference and willingness to pay for education on how to save water.	Qualitative research has not consistently separated water efficiency, campaigns, and devices, but customers have consistently shown support for the promotion of water efficiency measures. There is limited customer research on behaviour change, and it is closely linked to the use of water saving devices. Customers are supportive of reducing water usage and some value education over devices, or see the two as inseparable Customers demonstrated a preference for reducing demand as a priority over increasing supply and saw water efficiency as a key part of this.
C26-02	Promotion of Water Efficiency to customers- Education programme on water efficiency on different key stages (primary, secondary, further and higher education)	+++	Like C26-01, this option involves educating water users (younger generation who are unlikely to be bill payers) on water efficiency. Customers expressed a strong willingness to pay for this option.	
C26-03	Promotion of Water Efficiency to customers. Household water efficiency devices installation programme (Partnering or Company led approach, home visit), plus selective water saving devices ranging from 1-5 devices. This could include fitting of showers, low flow shower heads, cistern displacement, low flush toilets, dual flush toilets, timing devices, water butts, flush controllers for urinals, trigger nozzles for hoses, timing devices, fitting people detectors, spray taps and water efficient taps.	+++	Household and non-household customer expressed a strong willingness to pay for water saving devices. This option would not directly affect the service level of Bristol Water in terms of service failures (e.g. road works) however it would improve the overall service provided by Bristol Water.	
CO8	Selective metering of domestic customers based on high consumption e.g. sprinkler use and/or zones of high demand	---	Customers expressed a strong un-willingness to pay for metering (compulsory). Although this option would improve service levels and the potential reduction of TUB or NEUB bans, customer did not show a willingness to pay for metering which is not optional.	Results from qualitative research studies demonstrated that customers didn't tend to prioritise metering, or held very conflicting views. There is also a challenge in that customers prioritise leakage, but not metering, so it's possible that customers struggle to reconcile impacts on individuals with more generalised impacts, or that they don't fully understand the connection between leakage and metering. This could benefit from further exploration to better understand customer views, but certainly there is a clear message from current research that metering is not a priority.
C12	Enhanced promotion of free water meters to unmeasured households beyond the promotion assumed in baseline demand forecast	+	Customers expressed an un-willingness to pay for compulsory water meters however they were willing to pay for a 1% increase in meter penetration. This option is therefore partially in line with customer preferences	
C20	Installation of rainwater harvesting in new build households and non-households		This option does not directly fall under any of the options presented to the household and non-household customers surveyed. Rainwater harvesting would be a re-use of water and not necessarily a water saving device. However, given that rainwater harvesting would help customers to save water and customers expressed a strong willingness to pay for water saving options, should this option be implemented it would be in line with customer views. Harvesting rainwater would also benefit service failures by reducing TUB and NEUB.	Qualitative research has not consistently separated water efficiency, campaigns, and devices, but customers have consistently shown support for the promotion of water efficiency measures. Although rainwater harvesting is not directly a water saving device it does involve the re-use of water and would save water. There is limited customer research on behaviour change, and it is closely linked to the use of water saving devices. Customers are supportive of reducing water usage and some value education over devices, or see the two as inseparable. Customers demonstrated a preference for reducing demand as a priority over increasing supply and saw water efficiency as a key part of this.
P01-01	Increase performance of existing sources (P01-01R) to increase deployable output to near licensed volume	+	Household customers expressed an unwillingness to pay for the increased use of current water resources however non-household customers expressed a strong willingness to pay for this option. This option is therefore partially in line with customer preferences. Furthermore, this option does not involve additional abstraction beyond the current licence limit.	In a series of deliberative events exploring water resource options, customers viewed maximising current water sources as a logical priority for increasing water supply as part of a general tendency to support measures seen as efficient. Some customers prioritised this over leakage reduction when considering the cost effectiveness of both options side by side.
P01-02	Increase performance of existing sources (P01-02R) to increase deployable output to near licensed volume	+	Like P01-01, HH and NHH customers were split with HH customers expressing an unwillingness to pay whereas NHH customers expressed a willingness to pay for	

Option Number	Option description	Preference for Option	Economic Valuation	Non-valuation research findings
			increased use of current water resources. This option would also be within the current licence limits and not additional abstraction at the existing resources. Therefore, this option is also partially in line with customer preferences.	
P06	Catchment Management of the Mendip Lakes (P39R, P42R and P10R) to manage outage risk from algal blooms	+	This option does not fall into the categories presented to customers in the survey therefore it is not possible to assess its compatibility with customer preferences. The scheme is expected to be seen positively due to wider social and environmental benefits the scheme will bring.	No customer research conducted on catchment management to date. However, customers have expressed positive willingness to pay for environmental improvements in general. In the deliberative events which explored water resource options, one option presented was to improve environmental resilience through measures like catchment management. There was some support for this, although customers often struggled to see a clear link.
P08	P08R WTW (increased production)	+	As with P01-01 and P01-02, customers had a split view about increasing the use of current water resources. Thus this option is partially in line with customer preference.	In a series of deliberative events exploring water resource options, customers viewed maximising current water sources as a logical priority for increasing water supply as part of a general tendency to support measures seen as efficient. Some customers prioritised this over leakage reduction when considering the cost effectiveness of both options side by side.
P10	P10R WTW (increased production)	+	Like P10, customers had split views about increasing current water resources with household customers expressing an unwillingness to pay however non-household customers expressing a strong willingness to pay. This option is therefore partially in line with customer preferences.	
P20	Reduced leakage from raw water mains (enhanced leakage detection / raw mains repairs/replacement)	+++	Customers expressed a strong willingness to pay for reducing leakage in the Bristol Water system. This option would also significantly improve service levels with reduced unplanned interruptions in supply being experienced. This option is therefore compatible with customer preferences.	The qualitative results and the ongoing customer contact support leakage as being a top priority for customers. The ongoing insight shows that it is a key area for improvement. However due to customer views on metering, a wide understanding that leakage is an attribute that customers care about "for its own sake", it is also an area that warrants further customer research.
R08-02	New water sources within Bristol Water CAMS area for the location R08-02R	N	Customers had a split view with regards to developing new resources. Household customers expressed a strong unwillingness to pay whereas non-household customers expressed a slight willingness to pay. Given that household customers were not particularly keen to pay for new water resources options and only a small proportion of NHH customers were willing to pay, this option has been assessed as neutral about customer preferences.	Customers placed a low priority on developing new water sources, preferring options that focused on reducing demand and improving the effectiveness of current sources.
R08-03	New water sources within Bristol Water CAMS area for the location R08-03R	N	See R08-2	
R11	P10R Reservoir Standard WRMP14 design	N	See R08-2.	
R23	Purchase water from third parties from water companies	+	Household customers were unwilling to pay for third party water transfers however non-household expressed a strong willingness to pay for this. Therefore, this option is partially in line with customer preferences.	Customers asked about water trading found it difficult to give their full support without further additional information about the way this would be regulated, articulating unease about price gouging and the efficiency of transporting water long distances.
R24	Bring R24R source back into supply	+	Like P01-01, P01-02 and P08 customers has a split view on increasing the use of existing water resources. This option is therefore partially in line with customer preferences.	In a series of deliberative events exploring water resource options, customers viewed maximising current water sources as a logical priority for increasing water supply as part of a general tendency to support measures seen as efficient. Some customers prioritised this over leakage reduction when considering the cost effectiveness of both options side by side.
D21.01	Active Leakage Control (ALC) covers the continuation of the current leakage detection find and fix policy	+++	Active Leakage Control (ALC): enhanced leak detection and repair activities beyond our baseline leakage policy to reduce leakage to 36.5 Ml/d over the years	The qualitative results and the ongoing customer contact support leakage as being a top priority for customers. The ongoing insight shows that it is a key area

Option Number	Option description	Preference for Option	Economic Valuation	Non-valuation research findings
			2020/21 -2024/25 (2.83Ml/d).	for improvement. However due to customer views on metering, a wide understanding that leakage is an attribute that customers care about “for its own sake”, it is also an area that warrants further customer research
D21.02	Active Leakage Control (ALC) covers the continuation of the current leakage detection find and fix policy	+++	Active Leakage Control (ALC): enhanced leak detection and repair activities to reduce leakage from 36.5 to 35.0 (0.5 in 2029/30 and 1Ml/d in 2034/35)	The qualitative results and the ongoing customer contact support leakage as being a top priority for customers. The ongoing insight shows that it is a key area for improvement. However due to customer views on metering, a wide understanding that leakage is an attribute that customers care about “for its own sake”, it is also an area that warrants further customer research
D23	Asset Renewal involves the replacement and renewal of trunk mains	+++	This option involves the replacement and renewal of assets, mainly trunk mains to maintain good conditions of Bristol Waters infrastructure to reduce leakage. All customers expressed a strong willingness to pay for leakage reduction.	Customer research did not directly consider the renewal of assets however maintaining the network would help to reduce leakage and increase performance.

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14.8.1 Options compatibility with customer preferences

In summary, most of our WRMP19 options are compatible with their customer preferences. Schemes which address leakage and promote water efficiency were more favourable in comparison to new water resource options or metering (not optional).

Seven of our WRMP options have been assessed as very compatible with the preferences of our customers. Eight options have been assessed as having minor issues associated with customer preferences for solutions and therefore are not fully compatible. Three of the options (R0802, R08-03 and R11) have been assessed as being neutral to customer preferences as they are compatible with some of our customers, but not with others. One of the options (C08) has been assessed as not compatible with customer preferences and one has not been possible to assess as the option was not included specifically in any of the customer research questions (C20).

Option (C08) involves selective domestic metering based on high consumption areas (e.g. those that use sprinklers or are in an area of high demand). Both household and non-household customers expressed a strong unwillingness to pay for this option. Results of the qualitative research did show that customers had an appreciation of metering and did feel that it would be fairer to pay for what you use. Thus, rolling out metering that has free installation may be something customers are more willing to adopt.

During the consultation on the draft WRMP, the options presented in the preferred programme were further tested with customers. This process included deliberative workshops to explore customer preferences; willingness-to-pay research and customer preference testing of the overall plan proposed. Our deliberative customer research workshops identified that participants favoured maximising current water sources and Improving the distribution network as more cost-effective, efficient, less disruptive, and environmentally-friendly supply options than creating new sources. Most participants were opposed to developing new water sources at this stage due to the high cost, disruption, and environmental impact; especially considering leakage and options to improve the existing system. Some participants liked water trading because they believed that the UK has enough water, "it just needs to be moved to where it's needed"; although some felt it does not solve the problem, but simply moves it around. A few participants were concerned about water trading leading to higher bills.

Participants acknowledged that fixing leaks is increasingly expensive as you approach zero leaks, but still felt that it was essential to reduce leakage. In order to test the extent to which customers felt that leakage should be reduced, further testing was carried out with customers to examine the option of leakage reduction by less than 15%, a 15% target and leakage reduction by more than 15%. This identified that a majority of customers supported the idea of leakage reduction by at least 15%, but most customers did not support greater reductions in leakage due to the impact this could have on bills. When we tested our overall PR19 business plan with customers, including our proposed reductions in leakage and long-term management of a resilient supply, customer acceptability of our overall plan was 93%.

14.9 Environmental and Social Policy Review and Assessment

Table 14-5 shows how our draft WRMP options meet the environmental and social policy expectations of government and the environmental regulators. The review demonstrates that the majority of the options are aligned to the policy goals but a small number of options are not compatible with some specific policy objectives. The degree and strength of alignment of the different options to the policy goals has been considered in helping to determine our final best value plan, as described in the following sections.

Table 14-5: Results of the feasible options assessment against environmental policy

Option Number	Option description	WFD (RBMP)	HRA	WRMP Direction for 2017 (Carbon)	Water Resources Planning Guidance/Defra Guiding Principles										
					Trading/ Collaborations	Third Party Options	Flexibility	Customers Preferences	Catchment Management	Water Efficiency & Reuse	Leakage Control	Resilience/ Reliability	Sustainable Abstractions	National Environment Legislations	INNS
C26-01	Promotion of Water Efficiency to customers- Enhanced water efficiency communications campaign (different messages for different seasons)	+++	+++	N	N	N	++	+++	N	++	+	+	+	+	N
C26-02	Promotion of Water Efficiency to customers- Education programme on water efficiency on different key stages (primary, secondary, further and higher education)	+++	+++	N	N	N	++	+++	N	++	+	+	+	+	N
C26-03	Promotion of Water Efficiency to customers. Household water efficiency devices installation programme (Partnering or Company led approach, home visit), plus selective water saving devices ranging from 1-5 devices. This could include fitting of showers, low flow shower heads, cistern displacement, low flush toilets, dual flush toilets, timing devices, water butts, flush controllers for urinals, trigger nozzles for hoses, timing devices, fitting people detectors, spray taps and water efficient taps.	+++	+++	N	N	N	+++	+++	N	++	+	+	+	+	N
CO8	Selective metering of domestic customers based on high consumption e.g. sprinkler use and/or zones of high demand	+++	+++	N	N	N	N	---	N	++	+	+	+	+	N
C12	Enhanced promotion of free water meters to unmeasured households beyond the promotion assumed in baseline demand forecast	+++	+++	N	N	N	+	+	N	++	+	+	+	+	N
C20	Installation of rainwater harvesting in new build households and non-households	+++	+++	N	N	N	N	N*	N	++	N	N	+	+	N
P01-01	Increase performance of existing sources (P01-01R) to increase deployable output to near licensed volume	+	+++	N	N	N	N	+	N	+	N	+++	N	N	N
P01-02	Increase performance of existing sources (P01-02R) to increase deployable output to near licensed volume	+	+++	N	N	N	N	+	N	+	N	+++	N	N	N
P06	Catchment Management of the Mendip Lakes (P39R, P42R and P10R) to manage outage risk from algal blooms	+++	+++	N	N	N	+	N*	+++	N	N	+++	N	++	++
P08	P08R WTW (increased production)	+	+++	N	N	N	N	+	N	+	N	+++	N	N	N
P10	P10R WTW (increased production)	+	+++	-	N	N	N	+	N	+	N	+++	N	N	N
P20	Reduced leakage from raw water mains (enhanced leakage detection / raw mains repairs/replacement)	+++	+++	N	N	N	+	+++	N	N	+++	+	++	+	N
R08-02	New water sources within Bristol Water CAMS area for the location R08-02R	-	+	-	N	N	N	+	N	N	N	+	+	N	N
R08-03	New water sources within Bristol Water CAMS area for the location R08-03R	-	+	N	N	N	N	+	N	N	N	+	+	N	N
R11	P10R Reservoir Standard WRMP14 design	-	+	-	N	N	-	+	N	N	N	+++	-	-	-
R23	Purchase water from third parties from water companies	N	+	-	N	+++	+	+	N	N	N	++	N	N	N
R24	Bring R24R source back into supply	N	+	N	N	N	N	+	N	N	N	+	+	N	N
D21.01	Active Leakage Control (ALC): enhanced leak detection and repair activities beyond our baseline leakage policy to reduce leakage to 36.5 Ml/d over the years 2020/21 - 2024/25 (2.83Ml/d).	+++	+++	+	N	N	+	+++	N	N	+++	+	++	++	+
D21.02	Active Leakage Control (ALC): enhanced leak detection and repair activities to reduce leakage from 36.5 to 35.0 (0.5 in 2029/30 and 1Ml/d in 2034/35)	+++	+++	+	N	N	+	+++	N	N	+++	+	++	++	+
D23	Asset Renewal involves the replacement and renewal of trunk mains	+++	+++	N	N	N	++	+++	N	N	+	+	N	N	N+

N* - Option not included in customer preference survey

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15 Programme Appraisal

Section Overview

We have examined all the potential options and combinations of options, using a fully flexible optimisation programme which allows a range of objective functions against which to optimise. The optimisation programme has been developed by University of Exeter and HR Wallingford and is based on methodologies agreed with regulators as appropriate for the low level of concern derived from our formal problem characterisation.

The modelling tool has a high degree of automation, and this has allowed a strong audit function where options, and associated inputs and outputs, are stored and can be reviewed by external parties.

When the outputs have been assembled they have been subjected to additional scrutiny by an expert panel to test and confirm that overarching objectives of our customers are retained front and centre in the decision making process, in particular through reference to our customer research findings.

15.1 Programme appraisal and optimisation

We have followed the UKWIR 2016 WRMP decision-making methodology to review the options available to address the forecast supply deficit over the planning period and develop an optimised programme of measures to balance supply and demand. We have worked with University of Exeter and HR Wallingford to develop a fully flexible optimisation model that allows a range of objective functions against which to optimise. The approach is fundamentally based on the Economics of Balancing Supply and Demand (EBSD) approach as appropriate to the low level of concern derived from our formal problem characterisation. Due to the updated meter penetration forecast and improved baseline leakage reduction activities, no significant supply deficit is forecast. Consequently, instead of employing Multi-Criteria Analysis and Modelling to Generate Alternatives methods, we have decided to use adaptive pathways methods to investigate the impact of further leakage reduction and a decrease in PCC. Both scenarios would improve our supply-demand balance position hence we considered that there was no need to implement Multi-Criteria Analysis and Modelling to Generate Alternatives methods in view of the supply-demand balance forecast.

15.1.1 Approach and methodology

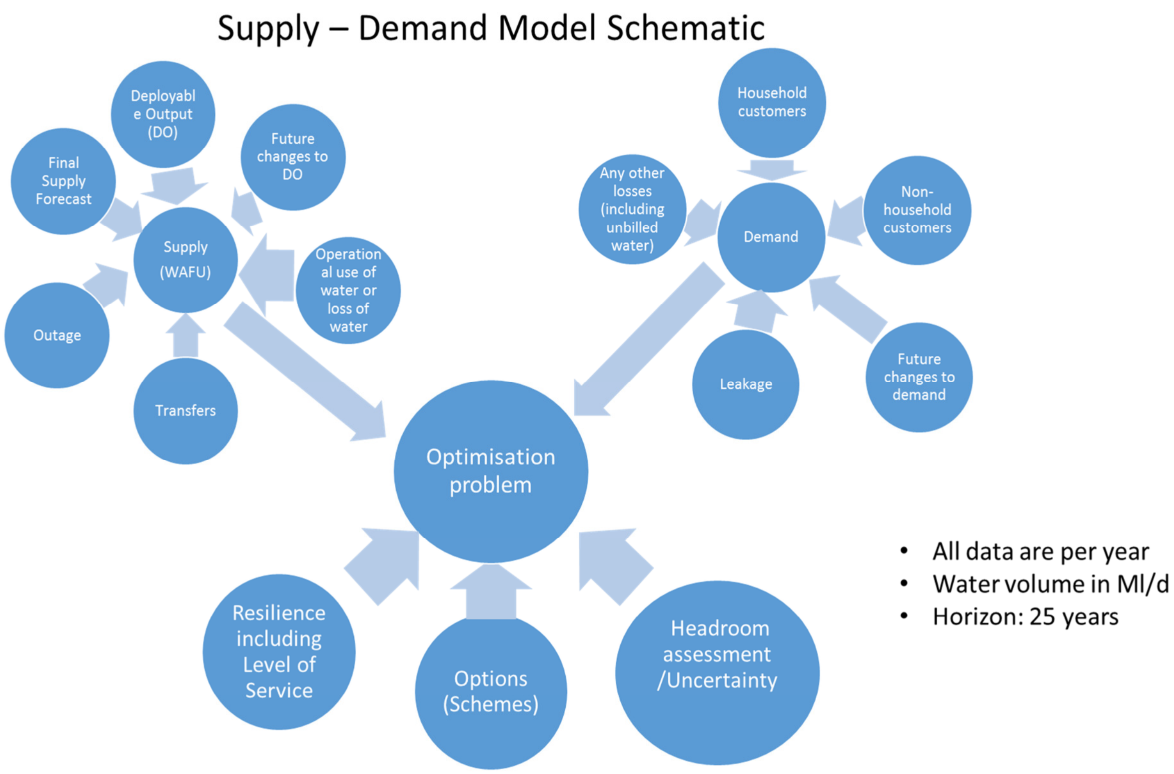
For WRMP19, we have invested in the development of a robust, in-house, fully integrated programme optimisation decision-support tool. This fully customised model meets our company specifications precisely, and covers all of our water resource planning optimisation requirements. We have full control over the data inputs, financial calculation processes and optimisation methods, and the underlying assumptions for each optimisation model run. The tool allows us to explore alternative strategies through optimisation on a range of different objective criteria, for example resilience or environmental performance in addition to identifying the least whole-life cost programme of measures. We have discussed the approach with the Environment Agency and explained the rationale for the choice of optimisation tool for developing this WRMP.

Our EBSD tool runs in the freely-available R software environment, and the EBSD script consists of 3 distinctive parts:

- Data import code from our WRMP tables.
- Data import code from our table of options (including data manipulation).
- Genetic algorithm code.

The key components of our EBSD model are shown in the schematic at **Figure 15-1**.

Figure 15-1: EBSD Model: Simplified Schematic



Our EBSD model has a modular structure enabling rapid updates of all the input parameters, including the ability to import supply and demand data from the WRMP, providing strong input/output data control. It also facilitates clear and transparent accessibility for decision-makers to all of the input and output data, providing confidence in the robustness of the optimisation processes.

For each feasible option, financial cost data, construction timeframes, carbon, environmental metrics (beneficial and adverse, as set out in **Section 14**), resilience benefits (as set out in **Section 13**) and deployable output/water saving benefit values are input to the model. Appropriate discount rates are also included to calculate the Net Present Value (NPV) of options and alternative programmes, using the discount rates provided in the Water Resources Planning Guideline (2017).

The optimisation algorithm is designed to allow the definition of more than one objective function and therefore can be used to solve multi-objective problems. The default objective function is defined as the function to minimise whole-life (NPV) cost over the planning horizon - assuming that there is no deficit between demand and supply at any time step. A constraint has also been added to prevent any supply deficit being allowed using a penalty function to the main cost function. Further objective functions can be user-defined to enable the solving of multi-objective problems (e.g. to optimise on resilience benefits or environmental performance). For such multi-objective problem solving, the EBSD model provides the Pareto Fronts of outputs for the combination of the least-cost solution and the other selected metrics - for instance, the total resilience score metric.

Model outputs are reviewed by the water resource planners and water company decision-makers: the outputs inform the decision-making process, but importantly the model is not the decision-maker. Expert judgement has been applied to the outputs and wider factors are also taken into consideration in determining the best value plan for balancing supply and demand over the planning period.

The model also enables scenario testing around the ‘best value’ plan to investigate the resilience of the plan to uncertainties and risks, for example climate change risks, future droughts being more severe than historic records and sensitivity to demand forecast or sustainability reduction assumptions.

15.2 Programme appraisal and decision making

Our programme appraisal modelling was used to investigate a range of alternative strategies to balance supply and demand to help inform decisions on the ‘best value’ plan. In particular, we were able to investigate the relative benefits of active leakage control measures and raw water losses reduction options, and the relative timing of implementing these demand management measures with lowest cost supply-side options. We also explored the alternative options that would need to be implemented in the event that the preferred solutions did not fully provide the required level of demand savings or deployable output benefits, giving us confidence that we had a resilient plan.

The model outputs provided included information on the NPV of the alternative strategies, the environmental and resilience performance, timing of implementation of each option relative to the supply-demand deficit and the lead times required for implementation.

The model data structure of inputs and outputs allowed a strong audit function where options, and associated data inputs and outputs, could be reviewed by both internal and external auditors, enabling robust review and challenge in the decision-making process. This included scrutiny by an expert panel to test and confirm that overarching objectives of our customers are retained front and centre in the decision-making process, in particular through reference to our customer research findings.

The draft decisions were also assessed in respect of compliance with regulatory requirements, the level of resilience provided, customer affordability and company financeability considerations, as well as taking account of regulatory and stakeholder expectations for the WRMP. The Plan was also subject to detailed environmental assessment through SEA, HRA and WFD assessment of the options making up the plan, both alone and in-combination. This showed that the options included in the draft plan had predominately negligible adverse effects and minor beneficial effects. We also assessed the draft plan against the government's policy objectives to ensure the options being included align to these objectives.

By reviewing the draft plan through these various different assessment "filters" and challenge processes, and making adjustments to the draft plan as a consequence, we have developed the 'best value' plan for customers and the environment, as presented in **Section 16**.

15.3 Adaptive Pathways

The programme appraisal described above is based on developing a highly resilient plan involving actions we know we can deliver with current technology. However, we do not want to limit our future ambition simply to the things we can do today. In light of this, we have also examined our longer term ambitious aspirations for the future (to 2050). This allows for the likelihood that there will be further improvements and innovation over the coming years (although we are not certain as to the specific supply-demand benefits these may bring). Recognising this, we have employed an adaptive pathways methodology in order to investigate the impact of the following scenarios on our WRMP19:

- Impact of PCC reduction to 110 litres/person/day (l/p/d) by 2049/50
- Impact of leakage reduction to 29Ml/d by 2049/50

15.3.1 PCC reduction to 110l/p/d by 2049/50

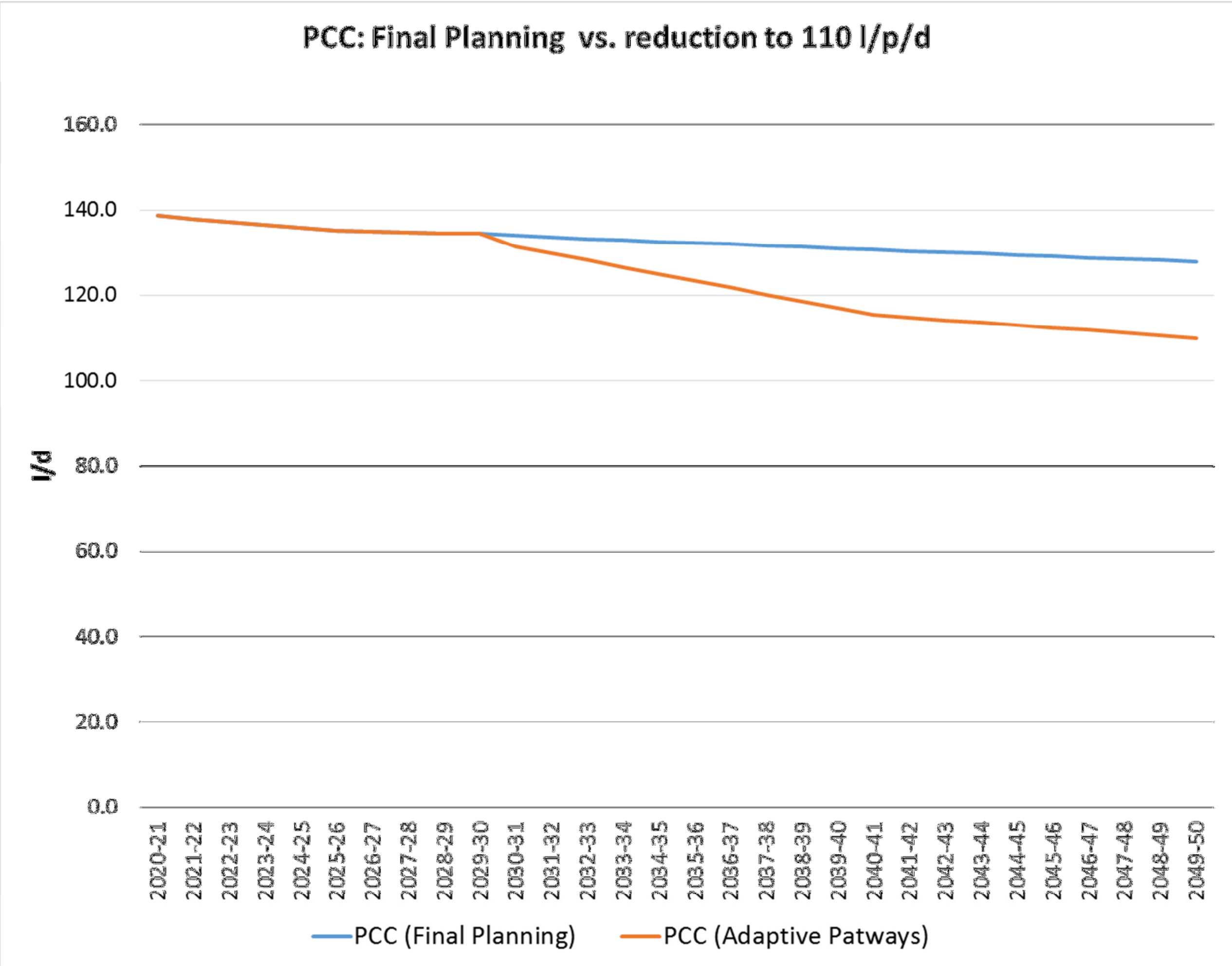
Our ambitious target is to reduce PCC to110l/p/d by 2049/50. The PCC for our final planning scenario and adaptive pathway scenarios is shown in the graph in **Figure 15-2**.

As part of WRMP19 we have investigated the changes to PCC presented in the report "The long term potential for deep reductions in household water demand", produced by Artesia Consulting for Ofwat (May 2018). From our analysis of this report and its two annexes, we have assumed that PCC decreases by 1.2 litres per person per year from 2016-2030, by 0.8 litres per person per year from 2031-2040, and finally by 0.3 litres per person per year from 2041-2050. In our adaptive pathway analysis we have assumed that radical change in PCC could potentially occur from 2030/31 onwards. In order to achieve our target of 110 l/p/d PCC in 2050, we have assumed that the year-on-year decrease would be twice that assumed in Artesia's report. Therefore for years 2030/31 to 2039/40 for the adaptive pathway assessment we have assumed a 1.6 litres reduction per year; and a 0.6 litres reduction per year for years 2040/41 to 2049/50.

We have assumed that technology shift is the major trigger to potentially impact on PCC from 2030/31 onwards. The potential export requirements from Bristol Water of our neighbouring companies from 2030/31 onwards could be another potential trigger event which drives further the requirement to reduce PCC, thereby ensuring there is a surplus of water supplies available for export.

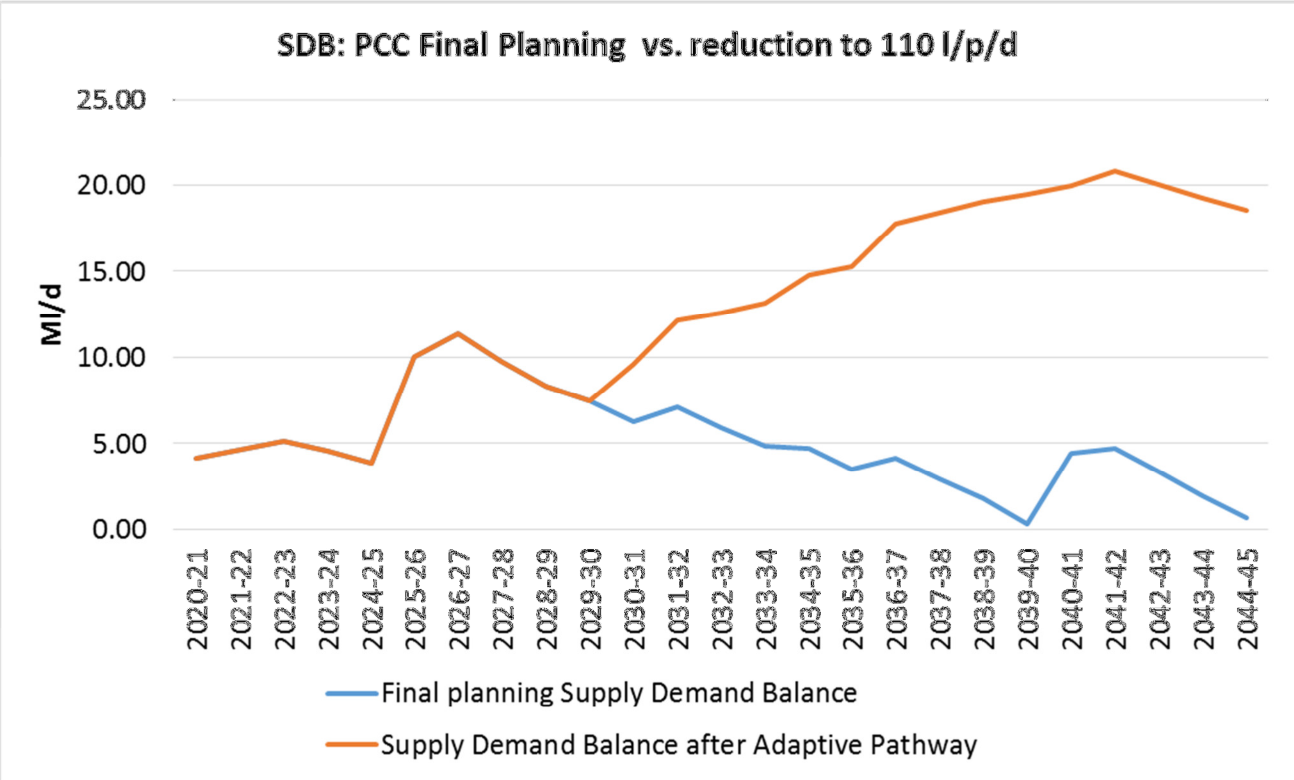
For our PCC reduction scenario, Option P20 - “Reduced leakage from raw water mains (enhanced leakage detection / raw mains repairs/replacement)” would no longer be required.

Figure 15-2: PCC for our final planning scenario and adaptive pathway scenarios



The supply-demand balance for our final planning scenario, and the supply-demand balance in our adaptive pathway PCC scenario, are presented in the graph in **Figure 15-3**.

Figure 15-3: Supply-demand balance (SDB) for final planning scenario and SDB for adaptive pathway PCC scenario



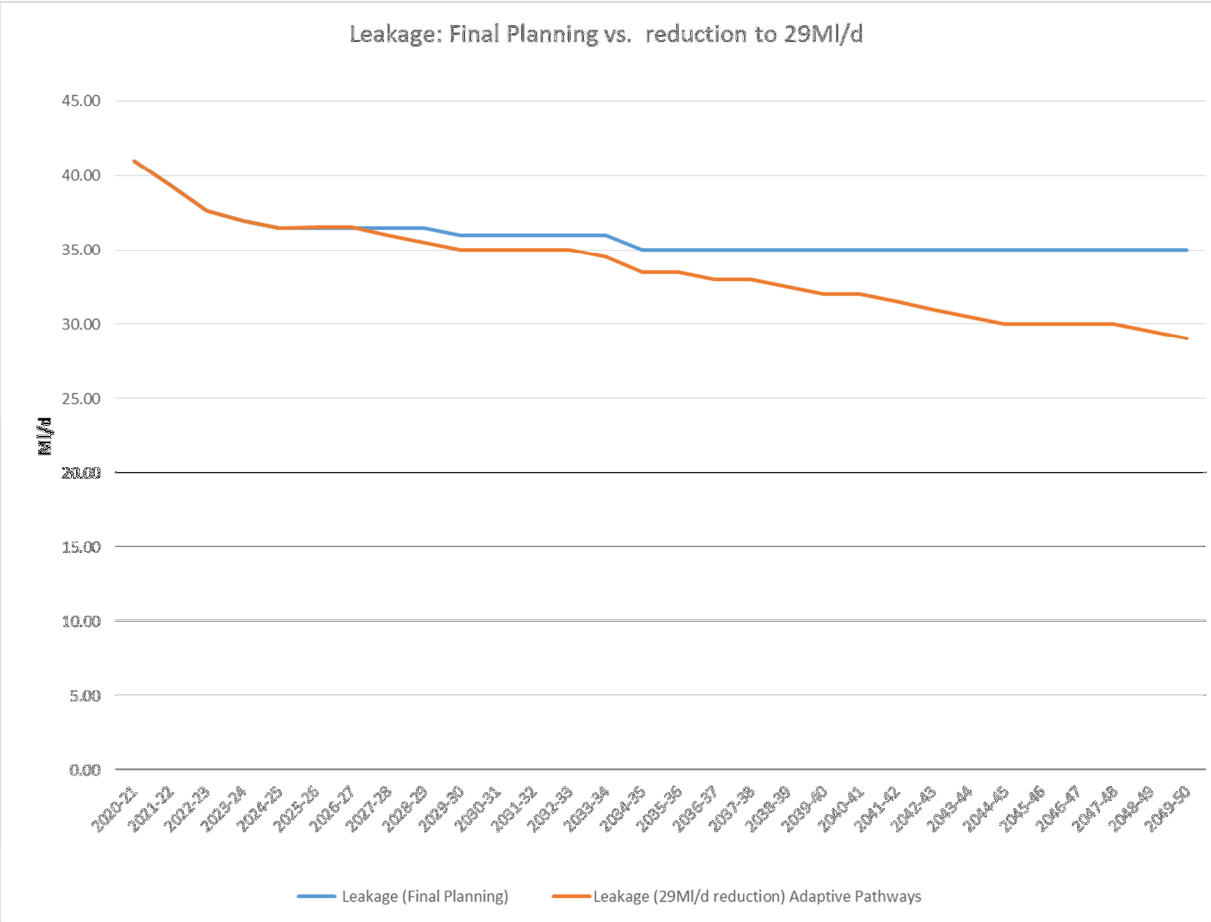
15.3.2 Scenario: Leakage reduction to 29Ml/d in 2050

Our ambitious target is to reduce leakage to 29 Ml/d by 2050. Leakage for our final planning scenario and for our adaptive pathway scenario is shown on the graph in **Figure 15-4**.

In order to achieve this target, we have modelled that a further reduction of 1 Ml/d is required during AMP8; a 0.5 Ml/d reduction in AMP9; a 1.5 Ml/d reduction in AMP10; a 2 Ml/d reduction in AMP11; and a 1Ml/d reduction in AMP12.

A major electricity price increase has been identified as part of the driver for further leakage reduction from 2025/26 onwards as this will increase water production costs relative to leakage reduction costs.

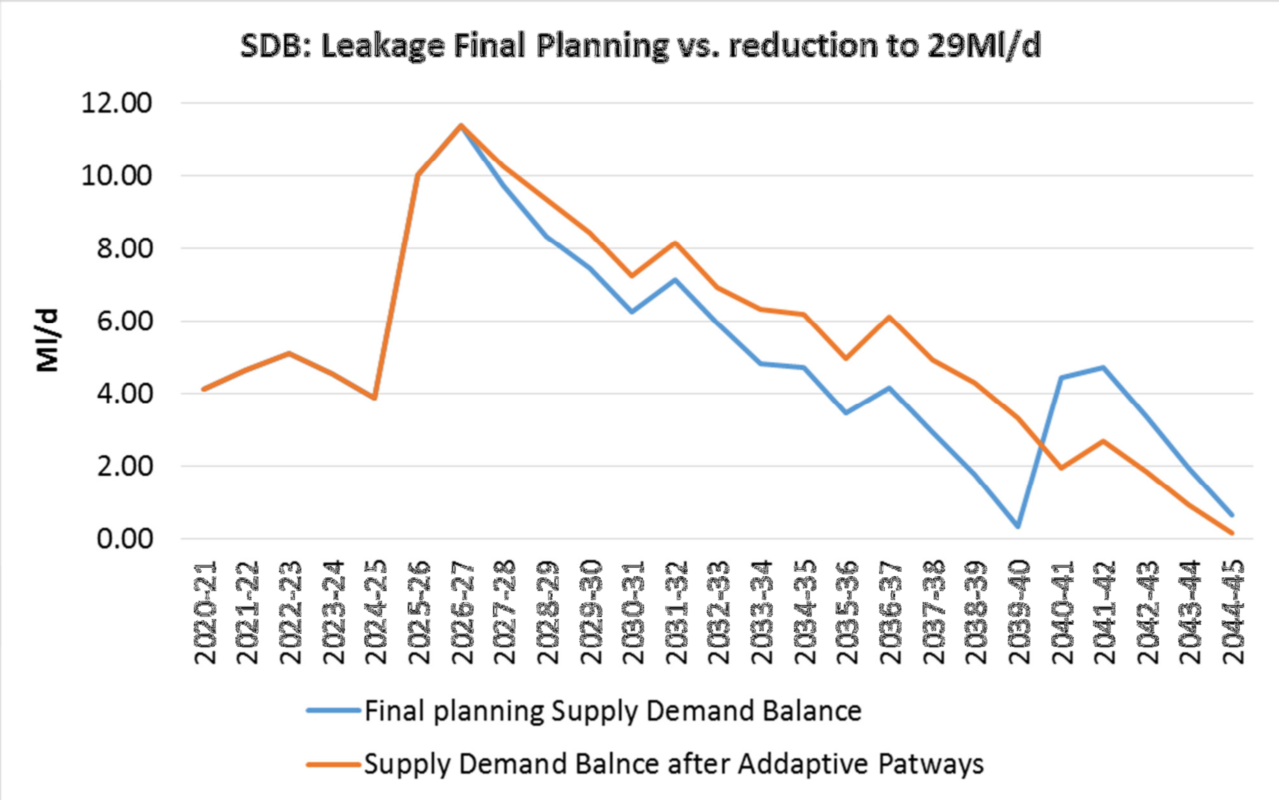
Figure 15-4: Leakage for final planning scenario and adaptive pathway scenario



The supply-demand balance (SDB) for our final planning scenario, and the supply-demand balance for our adaptive pathway for leakage scenario, are presented in the graph in **Figure 15-5**.

For the further leakage reduction scenario under the adaptive pathway assessment, option P20 – "Reduced leakage from raw water mains (enhanced leakage detection / raw mains repairs/replacement)" – would not need to be implemented before 2044/45, and could possibly be postponed until post-2045.

Figure 15-5: Supply-demand balance (SDB) - leakage for final planning scenario and adaptive pathway scenario



16 Final Water Resources and Demand Strategy

Section Overview

We have determined through extensive assessment, and the Bristol Water Board has confirmed overall acceptance, that our WRMP19 shall consist of the following activities and outcomes:

- Focussed efforts to continue to drive down leakage to achieve a 15% reduction by the end of 2025 (to 36.5 Ml/d) and to further reduce leakage in the longer term to 35.0 Ml/d by 2045, making use of new technologies and data systems as well as new installation and management techniques to ensure that reductions in leakage continue to be delivered at the best possible value.
- Work to reduce losses from our raw water systems in order to increase the amount of water available for us to reliably supply to customers.
- Reduce the amount of water exported to Wessex Water in dry weather conditions after 2024/25, as agreed with Wessex Water. This will help ensure that we continue to maintain reliable supplies to our customers in the longer term.
- Engagement with and support to our wide range of customers to help reduce demand through water efficiency advice, installation of water efficient products and promotion of household free meters, alongside enhanced education and awareness activities to demonstrate the value that this can bring to customers and the environment.
- We will also carry out further investigation of some of our abstractions as set out in the Water Industry National Environment Programme (WINEP) for the AMP7 period (2020-2025). These investigations may subsequently lead to a reduction in the amount we can abstract from certain water sources in agreement with the Environment Agency where the investigations conclude the current level of abstraction is detrimental to the environment.
- We will update and improve our own data acquisition and analytics to help support a closer and more accurate assessment of our operations.

We are confident that the above approach will continue to provide a cost effective, reliable and resilient service to our customers and will support us in our mission to continually improve knowledge of our system strengths and vulnerabilities, so that we continue to develop our efficiency and effectiveness whilst improving resilience. Our plan is aligned to our customers' preferences, as well government policy and regulatory expectations.

16.1 Introduction

From our comprehensive programme appraisal and decision-making process, we have developed our preferred plan to meet our target customer levels of service for water supply reliability in a cost-efficient, affordable and environmentally acceptable manner. Our plan aligns with government policy and regulatory expectations for future water resources management and delivery of a resilient water supply service to our customers.

16.2 Final Planning Supply Demand Balance

Our preferred approach to securing a supply-demand balance over the 25 year planning period is focused on leakage reduction activities to achieve a 15% reduction in leakage by the end of 2025 (to 36.5 Ml/d) and to further reduce leakage in the longer term to 35.0 Ml/d by 2045. This strategy is driven in part by a strong customer preference (including from customer research before and after publication of the draft WRMP19 as well as customer responses to our draft WRMP19 consultation) to prioritise leakage reduction before we develop any new water sources. Additionally, our regulators and other stakeholders have given a strong message in their responses to the draft WRMP19 that we should be more ambitious in our leakage targets, going beyond current SELL-derived targets. This will be achieved via Active Leakage Control (Options D21.1 and D21.2).

From 2040/41, we will also reduce leakage (losses) from our raw water mains by 5.5 Ml/d (Option P20) although it is anticipated that we could see some reductions before this date from our ongoing maintenance programmes of our raw water system and at our water treatment works, but this is not guaranteed.

The profile of the implementation of these three WRMP options is presented in **Figure 16-1**. The final supply demand balance position is presented in **Figure 16-2**.

Figure 16-1: Implementation of the WRMP options during the planning period

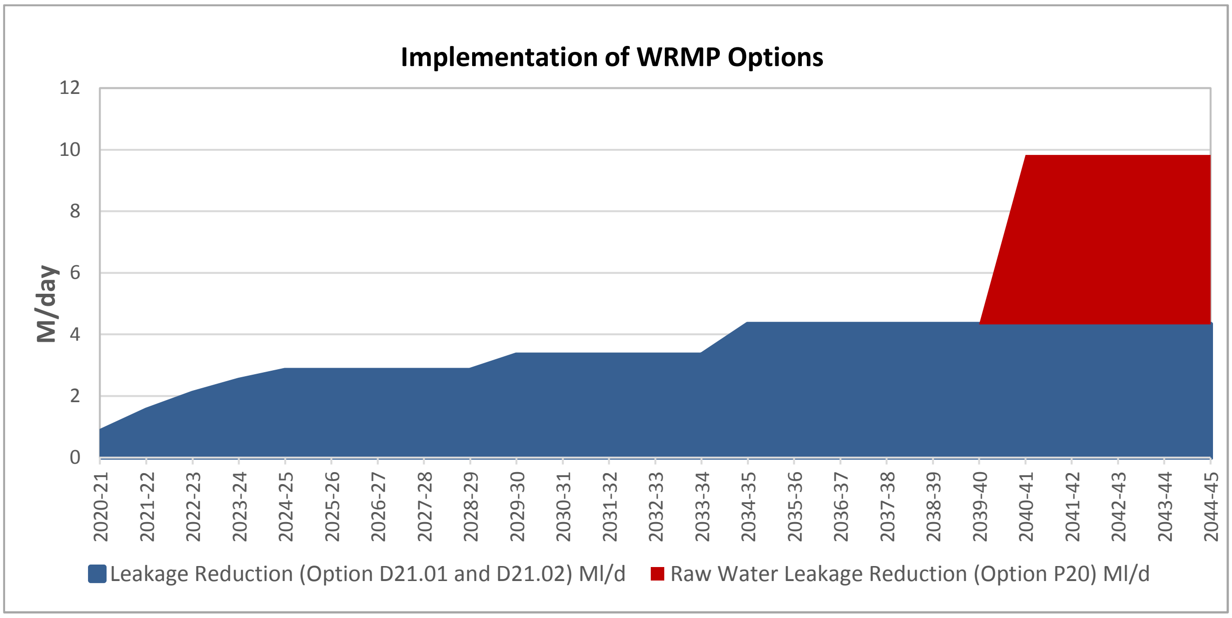
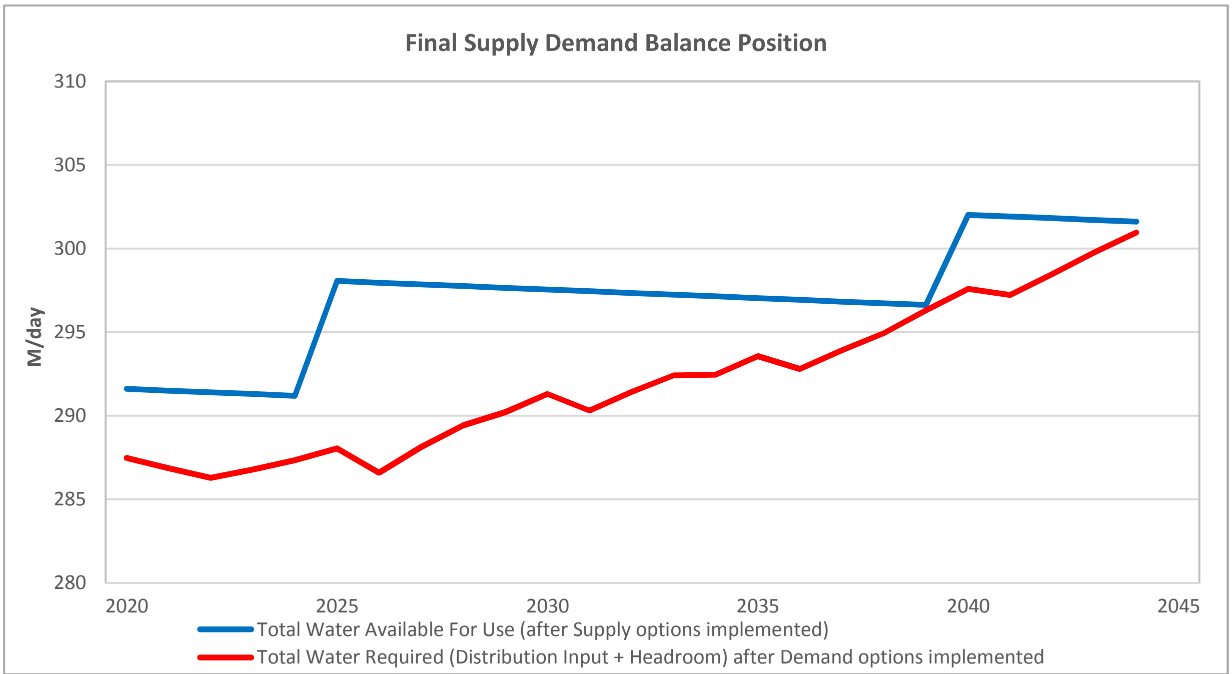


Figure 16-2: Final Supply Demand Balance Position



These actions are additional to the suite of activities that underpin our baseline supply-demand balance forecast:

- Reducing leakage to a baseline position of 39.33 Ml/d by 2024/25
- Reducing our bulk export to Wessex Water from 11.37 Ml/d to 4.37 Ml/d after 2024/25, as agreed with Wessex Water
- Continuing to actively promote our free meter option and to meter households on change of occupier, increase meter penetration rates from 66% at the end of 2019/20 to 87% by 2044/45.
- Enhancing our water efficiency activities to complement our metering programme to reduce average dry year PCC down to at least 129.4 litres/person/day by 2044/45 as well as continuing research and innovation to help drive PCC down to our long-term ambition of 110 litres/person/day by 2050.

In view of the relatively small supply deficit and customer and regulatory support for use of demand-side options, we have not included any water trading options in our plan. Several trading options were considered (in addition to our baseline changes to our Wessex Water export), including an import from Wessex Water. However, we are able to address our forecast deficit through leakage reduction activities which customers view as the priority solution for us to adopt. We believe this is the best value plan for our customers and is only marginally more expensive than the pure least-cost plan which would have involved re-development of some groundwater sources. However, these carried a greater environmental risk due to possible WFD compliance concerns and therefore the leakage options have been selected in preference on both customer preference and environmental grounds.

16.2.1 Level of service and annual risks of water use restrictions

In developing our water resources strategy, we have ensured that we at least continue to meet our target levels of service for water use restrictions and have demonstrated that we can maintain supplies in at least a 1 in 200 year drought event (with Temporary Use Bans and Non-Essential Use Ban (NEUB) Drought Order restrictions in place to reduce demand).

We have assessed the actual level of service associated with each level of demand restriction as an average annual percentage risk at the beginning of each 5-year AMP period. The assessment was carried out by using forecast demand (distribution input) plus target headroom as a primary check against our demand restriction trigger levels, with a further check carried out using forecast Water Available For Use (WAFU). The results are provided in **Table 16-1a** and **Table 16b**. This shows that actual level of service will match the planned level of service for Temporary Use Bans and Non-Essential Use Ban (NEUB) Drought Orders over the entire planning horizon. Our assessment of the actual risks of needing emergency drought orders exceeds our WRMP14 target level of service of 1 in 100 years: we forecast that the risk is below 0.5% (1 in 200 years) once our Drought Plan measures are taken into account (Temporary Use Bans, Non-Essential Use Ban Drought Order and drought permits for our Mendip reservoirs). We have therefore updated our WRMP19 target levels of service to reflect this improved understanding. This analysis is supported by the modelling carried out with different drought return periods as shown in the drought response surface plots for the base year and the final year of the planning period (**Figures 16-1 and 16-2**). Demand plus target headroom does not vary materially across the planning horizon and the risk of water use restrictions is therefore the same over the 25 year period. Whilst drought response surfaces have not been produced for other years, the pattern would be virtually identical for each 5-year period.

Table 16-1a: Calculated levels of service per 5 year periods across the 25-year planning horizon (using demand + target headroom)

	AMP 7		AMP 8		AMP 9		AMP 10		AMP 11	
	2020/21 to 2024/25		2025/26 to 2029/30		2030/31 to 2034/35		2035/36 to 2039/40		2040/41 to 2044/45	
Demand + Target Headroom	**287.48 Ml/d maximum**		**290.21 Ml/d maximum**		**292.44 Ml/d maximum**		**296.30 Ml/d maximum**		**300.96 Ml/d maximum**	
Demand restriction	**Target LoS**	**% annual risk**	**Target LoS**	**% annual risk**	**Target LoS**	**% annual risk**	**Target LoS**	**% annual risk**	**Target LoS**	**% annual risk**
TUBs	1 in 15 year	6.67	1 in 15 year	6.67	1 in 15 year	6.67	1 in 15 year	6.67	1 in 15 year	6.67
Drought Order (NEUB)	1 in 33 year	3.03	1 in 33 year	3.03	1 in 33 year	3.03	1 in 33 year	3.03	1 in 33 year	3.03
Emergency Drought Order	1 in 200 years	<0.5	1 in 200 years	<0.5	1 in 200 years	<0.5	1 in 200 years	<0.5	1 in 200 years	<0.5

Table 16-2b: Calculated levels of service per 5 year periods across the 25-year planning horizon (using WAFU)

	AMP 7		AMP 8		AMP 9		AMP 10		AMP 11	
	2020/21 to 2024/25		2025/26 to 2029/30		2030/31 to 2034/35		2035/36 to 2039/40		2040/41 to 2044/45	
Total WAFU	268.24 Ml/d minimum		268.99 Ml/d minimum		273.53 Ml/d minimum		276.58 Ml/d minimum		300.96 Ml/d minimum	
Demand restriction	**Target LoS**	**% annual risk**	**Target LoS**	**% annual risk**	**Target LoS**	**% annual risk**	**Target LoS**	**% annual risk**	**Target LoS**	**% annual risk**
TUBs	1 in 15 year	6.67	1 in 15 year	6.67	1 in 15 year	6.67	1 in 15 year	6.67	1 in 15 year	6.67
Drought Order (NEUB)	1 in 33 year	3.03	1 in 33 year	3.03	1 in 33 year	3.03	1 in 33 year	3.03	1 in 33 year	3.03
Emergency Drought Order	1 in 200 years	<0.5	1 in 200 years	<0.5	1 in 200 years	<0.5	1 in 200 years	<0.5	1 in 200 years	<0.5

Figure 16-1 Drought Response Surface Plot (Base Year 2017/18)

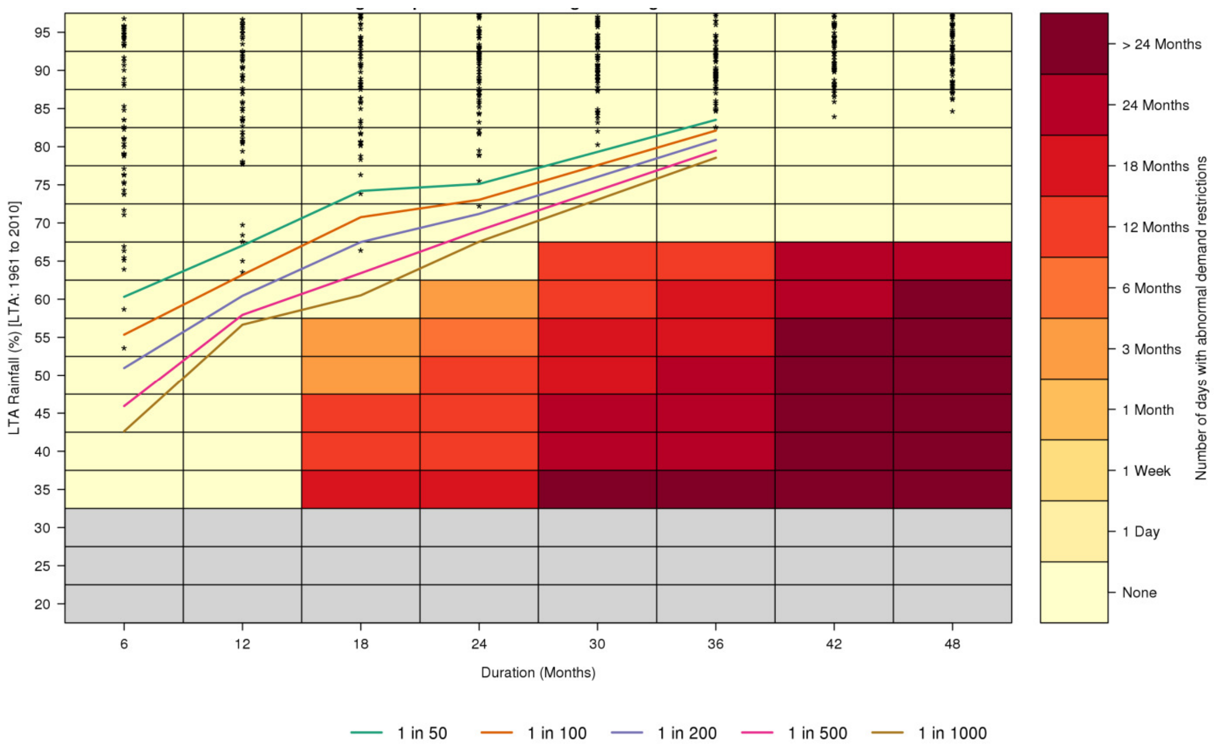
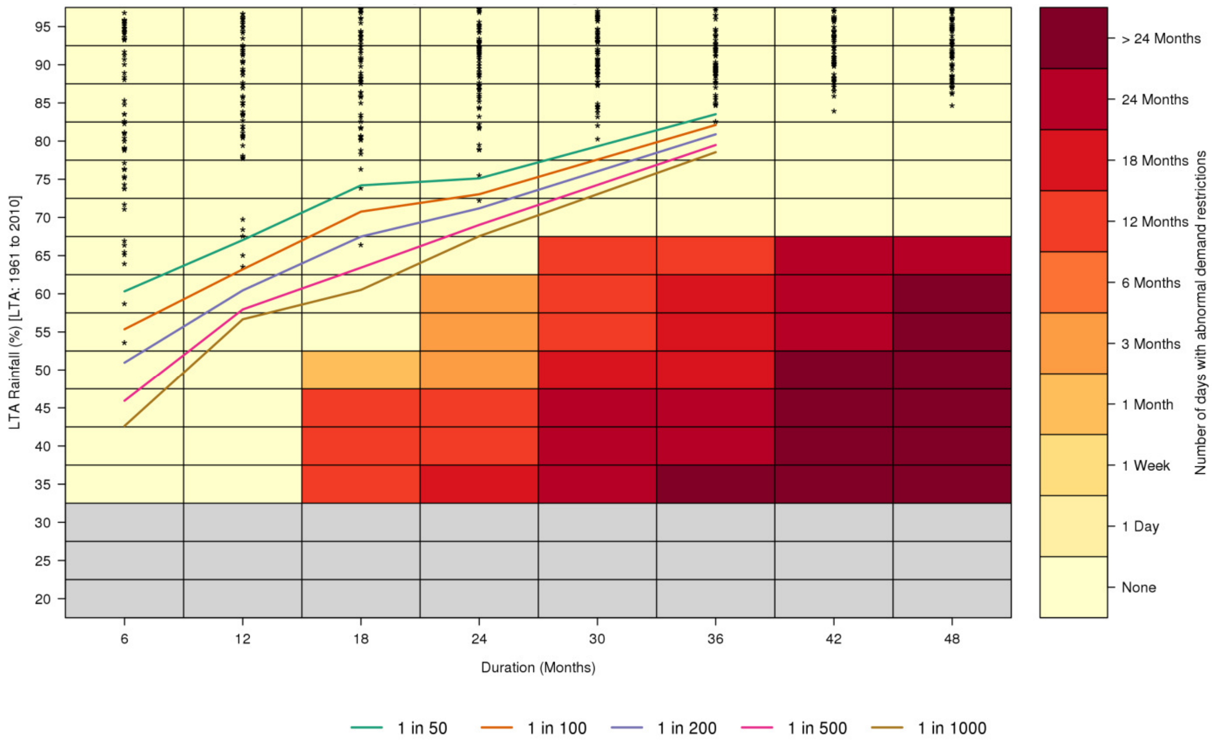


Figure 16-2 Drought Response Surface Plot (2044/45)



Following the revisions made to our hydrological modelling for the WRMP19, we will be carrying out a review of our Drought Plan trigger levels to take account of the latest evidence about the risks of requiring water use restrictions and drought permits. As we confirmed in our Final Drought Plan 2018, we will be reviewing the abstraction control curves for operation of our raw water reservoirs which drive our drought triggers. This will include consideration of optimal operating regimes that balance environmental protection and supply reliability risks to our customers. We will engage with the Environment Agency, Natural England and other relevant stakeholders as part of this review.

16.3 A Customer-Focused Strategy

Customer preference for leakage reduction is high and by taking account of this preference in cost-benefit analysis, our preferred plan includes leakage reduction of 15% by the end of AMP7 (2024/25) to a level of 36.5 Ml/day and to further reduce leakage to 35.0 Ml/d by 2044/45. We will also reduce leakage from our raw water system from 20.27 Ml/d to 14.77 Ml/d from 2040/41 to maintain supply reliability standards for our customers.

Bristol Water has a clear mandate from its customers to set ambitious service targets whilst also reducing water bills. Our Business Plan submission to Ofwat (September 2018) confirms that, taking the overall expenditure requirements into account for our water supply service to customers, including the leakage reduction activities, water bills are set to remain below the levels seen in 2015 throughout the period 2020-2025, even after inflation effects. After forecast inflation, water bills in 2025 are set to be an average of £9 lower than they were in March 2015.

16.3.1 Prioritising leakage reduction

Our leakage performance is already better than the industry average. In our assessment of customer preferences around water resource management, our customers have showed a very high willingness to pay for reduction in leakage and this has been reinforced by the customer research we carried out on our draft WRMP19 and customer consultation responses to the draft plan. This has influenced our decision to include additional leakage reduction beyond the SELL in our final WRMP19. We consider that this strategy provides long-term value for our customers and the best possible balance of leakage management, resilience and customer bills taking account of current technology and innovation trends in leakage control.

We will continue to review this position over the AMP7 period as and when further innovation and technology changes materialise that may alter the cost-benefit assessment.

16.3.2 Other demand measures

A key outcome of customer engagement indicated that, in addition to leakage reduction, customers would prefer us to prioritise demand management measures over developing new water resources. Demand management measures include metering and water efficiency.

As detailed in **Section 8.2,** customer research regarding our metering approach was inconclusive, as a result we are not proposing to change our metering approach in this WRMP. This policy was broadly supported by customer research on the draft WRMP19 and customer responses to the draft plan consultation. Based on further assessment work since the draft WRMP19, we forecast being able to achieve 87% meter penetration by 2044/45 without any changes to our current metering policy. This, along with the strong customer preference for leakage as a means to address the forecast small supply deficit and the lower cost associated with leakage reduction, supports our stance on maintaining our existing metering approach (metering of new properties, promotion of meter optants and change of occupier metering), rather than accelerating the increased use of metering as an option to meet the forecast supply deficit. We also do not have the legal powers to implement compulsory metering.

Customers expressed a strong support for water efficiency and therefore we have proposed enhanced water efficiency measures with our customers in our baseline programme, as detailed in **Section 8.3** in order to reduce PCC and work towards our ambition of reducing PCC to 110 litres/person/day by 2050.

16.4 A Social & Environment-Focused Strategy

Each of the WRMP options has been assessed for the potential effects on society and the environment as detailed in **Section 14** and associated appendices. The preferred programme of options involves a reduction in treated and raw water leakage. Therefore, there are no increases to current abstraction rates via increased production or the development of new water resources. As a result the overall environmental effects are deemed low and negligible. Negligible environmental effects are anticipated from the reduced export to Wessex Water as the reduction will be offset from the use of existing licensed water sources by Wessex Water along with demand management activities. The outcome of the key assessments is presented in subsequent sections.

16.4.1 SEA of the Preferred Programme

The Potential Effects of the Preferred Combination of Options

We have identified three preferred options for balancing supply and demand. The findings of the detailed assessments of the preferred options during construction and operation are presented in **Table 16-2** and **Table 16-3**, and summarised in **Table 16-4.** The findings are discussed in more detail below.

Construction

The preferred options were assessed as having neutral effects against the majority of the objectives during construction. Significant negative effects were only identified for option P20 against climate change (Objective 6) and waste and resources (Objective 10). This is due to an increase in greenhouse gas emissions arising from embodied carbon associated with potential new sections of pipeline (or renewal of pipes) and emissions from plant and vehicle movements to repair and replace leaking mains (Objective 6) and due to increase in resource use and construction waste along with fuel usage for vehicles and plant (Objective 10), although against both objectives, some residual uncertainty remains due to the uncertain nature of the scale and location of the work to be undertaken.

Operation

The preferred options are assessed as having neutral or positive effects against all objectives during operation. Minor positive effects were identified for Objectives 3 (water quantity), 6 (climate change), 7 (human health), 8 (economic and social wellbeing), 9 (water resources) and 10 (waste and resource use). This is due to savings made by leakage reduction (Objectives 3 and 9), a reduction in annual greenhouse gas emissions (Objective 6), the greater resilience (Objective 7), ensuring a continual supply of clean drinking water (Objective 8), support economic growth in the area (Objective 8) and energy savings (Objective 10). The uncertainty against Objective 6 reflects the uncertainty associated with the operation of P20, and the precise extent to which the option would result in a decrease in demand for water abstraction and subsequent treatment with the commensurate reduction in energy demand and greenhouse gas emissions.

Summary of Effects

The summary of the construction and operational effects of the preferred combination of options outlined in **Table 16-4** illustrates the likely significant negative effects arising during the construction phase against the resulting significant positive effects from their subsequent operation. It is worth noting that the identified cumulative effects of construction may be overly cautious as the effects are actually spread over the plan period 2020 – 2045 (as different options are implemented through the lifetime of the Plan) with largely short term effects occurring as each option is implemented. No adverse effects, either alone or in combination, are anticipated on any

SSSIs or other nationally designated sites as a result of the preferred programme. Equally, none of the options in the preferred programme will have any adverse effects on our duties under the Natural Environment and Rural Communities Act 2006 to conserve biodiversity. Indeed, there is a potential benefit to biodiversity by reducing demand for water and thereby abstraction from the water environment

Table 16-3: Preferred Combination of Options – Construction Effects

Option	1. Biodiversity	2. Geology and Soils	3. Water Quantity	4. Water Quality	5. Flood Risk	6. Climate Change	7. Human Health	8. Economic and Social Wellbeing	9. Water Resources	10. Waste and Resource Use	11. Cultural Heritage	12. Landscape
D21.1: Active Leakage Control	0/?	0	0	0	0	-/?	0	-	0	-	0	0/?
D21.2: Active Leakage Control	0/?	0	0	0	0	0	0	-	0	0	0	0/?
P20: Reduced leakage from raw water mains (enhanced leakage detection / raw mains repairs/replacement)	0/?	0	0	0	0	--/?	-/?	+/-	0	--/?	0	-/?
Preferred combination of options	0/?	0	0	0	0	--/?	0/?	+/-	0	--/?	0	0/?

Table 16-4: Preferred Combination of Options – Operational Effects

Option	1. Biodiversity	2. Geology and Soils	3. Water Quantity	4. Water Quality	5. Flood Risk	6. Climate Change	7. Human Health	8. Economic and Social Wellbeing	9. Water Resources	10. Waste and Resource Use	11. Cultural Heritage	12. Landscape
D21.1: Active Leakage Control	0	0	+	0	0	+	+	0	+	0	0	0
D21.2: Active Leakage Control	0	0	+	0	0	+	+	0	+	0	0	0
P20: Reduced leakage from raw water mains (enhanced leakage detection / raw mains repairs/replacement)	0	0	+	0	0	0	0	0	+	0	0	0
Preferred combination of options	0	0	+	0	0	+/?	+	+	+	+	0	0

Table 16-5: Summary of the Preferred Combinations of Options – Construction and Operational Effects

Option	Stage	1. Biodiversity	2. Geology and Soils	3. Water Quantity	4. Water Quality	5. Flood Risk	6. Climate Change	7. Human Health	8. Economic and Social Wellbeing	9. Water Resources	10. Waste and Resource Use	11. Cultural Heritage	12. Landscape
Preferred combination of options (9.83 Ml/d)	C	0/?	0	0	0	0	--/?	0/?	+/-	0	--/?	0	0/?
	O	0	0	+	0	0	++	++	++	+/?	++	0	0

16.4.2 HRA

The assessment highlighted that screening of the leakage reduction options that form the preferred programme would not have a likely significant effect on any European site. It is acknowledged that construction-phase effects of the leakage reduction options cannot be meaningfully assessed at the plan-level as the location of any works required is not known and will be established as part of an ongoing programme of detection and repair. However, it is made clear that the options do not have a risk of unavoidable adverse effects, based on the scale and type of works expected and that established best-practice measures and scheme-level assessment can be relied on to ensure that no likely significant effects will occur to any European site.

The conclusion of the HRA of the WRMP is that the plan will have **no likely significant effects on any European site, either alone or in combination with any other projects or plans**. It is noted that this conclusion does not remove the need for consideration of Regulation 63 at the project-level, which will be required to address those aspects and uncertainties that cannot be meaningfully assessed at the plan-level, such as the effects of individual leakage-reduction schemes.

16.4.3 WFD Assessment

It is confirmed that the WRMP preferred programme only involves leakage reduction based options and that with no resource options included in the WRMP, no WFD assessment is required as the options fall out of the scope of the WFD assessment.

16.4.4 Greenhouse gas emissions and climate change effects

We assessed the effects of the WRMP19 preferred programme on greenhouse gas emissions. As set out in Section 14, the net greenhouse gas (carbon) emissions of the options that make up our preferred programme are small when considering the materials use necessary for leakage reduction activities and the reductions in water abstraction pumping and water treatment from reducing demand. The net change is estimated at 6361 tonnes of CO_2 equivalent of embodied carbon over the 25 year period. There is negligible net change in operational carbon, with vehicle and traffic related emissions minimised by use of electric fleet vehicles over the planning period weighed against some reduced abstraction and water treatment related emission benefits.

The effects of climate change upon the final planning scenario are assessed as small to negligible on the leakage reduction schemes that make up our preferred programme. Climate change may make pipes more prone to leakage due to soil shrinkage or expansion in warmer and/or wetter weather but the effects over the 25 year planning period are likely to be very small and this does not affect the delivery of the savings associated with these schemes.

The table below sets out the climate change implications associated with each of the three demand side options included in our WRMP19 preferred programme.

Option	Construction effects	Operation effects	Effect on yield (Ml/d)
D21.1 Active Leakage Control	Minor negative effect /uncertain	Minor positive effect	0
D21.2 Active Leakage Control	Neutral	Minor positive effect	0
P20 Reduced leakage from raw water mains	Significant negative effect	Neutral	0
Preferred combination of options	Significant negative effect	Significant positive effect	0

The significant negative effects associated with option P20 – Reduced leakage from raw water mains are associated with the increase in greenhouse gas emmissions airsing from embodied carbon associated with new pipeline and emmissions from plant and vehicle movements to repair and replace leaking mains. Due to the target driven nature of these leakage options they are not effected by climate change variability and therefore no allowance has been made for any variation in the option yield due to the effects of climate change.

16.4.5 Environmental and Social Policy Review

The assessment against environmental and social policy indicates that the preferred programme is either Neutral or Positive in supporting policy. Therefore it can be concluded that there will be no effect from the preferred programme.

16.5 Overview

This WRMP has identified sustainable and cost-effective measures to balance supply and demand to 2045 and maintain reliable supplies for our customers. The selection of options has largely been driven by cost and customer preferences. However, these options also 'score' highly in our social and environmental assessments which indicates our preferred programme is also socially and environmentally beneficial. Since publication of our draft plan, we have carried out further extensive customer preference testing on the draft plan to understand how our customers want us to deliver the demand savings, for example what kind of leakage approach and whether it will be worth doing more on metering and water efficiency work. This approach has included further testing on customer preferences around resilience, environmental and social benefits of all demand savings, as well as cost and customer willingness to pay.

Our testing supports that the proposals we have made in this plan to reduce leakage from our treated water network and raw water system to meet our customers' preferences for reducing demand before we seek to develop new water resources. Testing of our overall plan for AMP7 has shown that the customer acceptability of our preferred plan is 93%.

Reducing leakage creates additional resilience to Bristol Water and our customers, not just by reducing demand and hence increasing the available headroom, but from the extensive investigations of the supply network that will be necessary to reduce leakage down to the targets proposed. A key benefit of these investigations will be to further improve our knowledge of the likely vulnerabilities, performance and opportunities of the supply network. We believe that this will increase our ability to achieve an overall improvement to supply resilience as a result.

We regard the provision of safe high-quality drinking water as our top priority in planning for the service we provide and none of the options in our preferred plan would lead to any deterioration in water quality. In addition, our proposals for options which might need to be implemented in various different scenarios would also allow for provision of safe high-quality drinking water with no deterioration from the high standards that our customers rightly expect.

17 Testing the WRMP

Section Overview

We have undertaken a series of sensitivity tests of the WRMP19 preferred plan as part of our governance process to be able to demonstrate to our Board and external stakeholders the robustness of the plan to variability in some of the principal assumptions such as:

- Changes to WFD or Sustainability Assessment impacts on our sources – reducing the amount expected to be licensed
- Changes to the demand forecast due to changes in per capita consumption
- Changes to demand due to new industrial/commercial demand
- Changes to climate change impact assumptions on our source yields

Based on these sensitivity tests we have confidence that our plan is well based and coherent, and the testing has provided us with more insight into areas where we need to pay particular attention to possible variability and where improved data will add value.

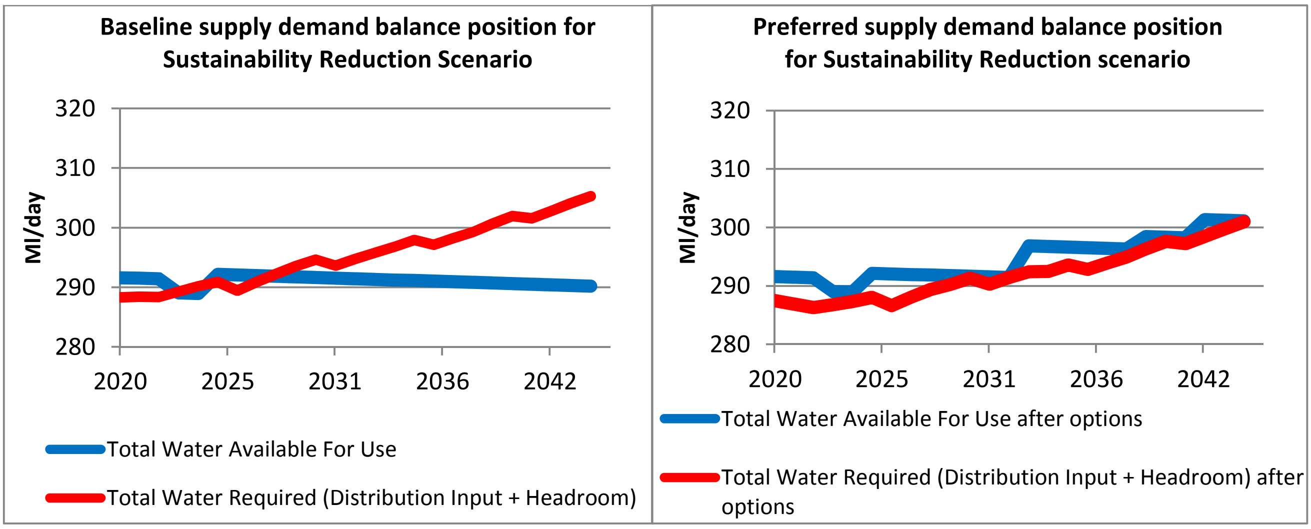
17.1 Overview

We have modelled further WRMP scenarios in order to test our preferred plan and ensure that, in the event of an unexpected change to demand or change in water available for use, options are available that can address any likely change without an unacceptable impact on customers. Our modelling demonstrates that under the scenarios assessed, we will have a range of viable options available that address any future supply-demand balance deficit. The scenarios assessed are discussed in the following sections.

17.2 Scenario 1: Sustainable Abstraction obligations

This scenario has assumed that the risk of future Sustainability Reductions (as detailed in **Section 9**) materialise and are actually required, resulting in a reduction of 5.9 Ml/d in deployable output (based on our current discussions with Environment Agency). It is assumed that the sustainability reductions would be implemented by 2025 following investigation between 2020 and 2025. **Figure 17-1** demonstrates that the supply-demand balance can still be maintained in this scenario through reduction in leakage, including raw water leakage, and implementation of drought management options at our P42R and P39R Reservoirs when necessary during drought conditions.

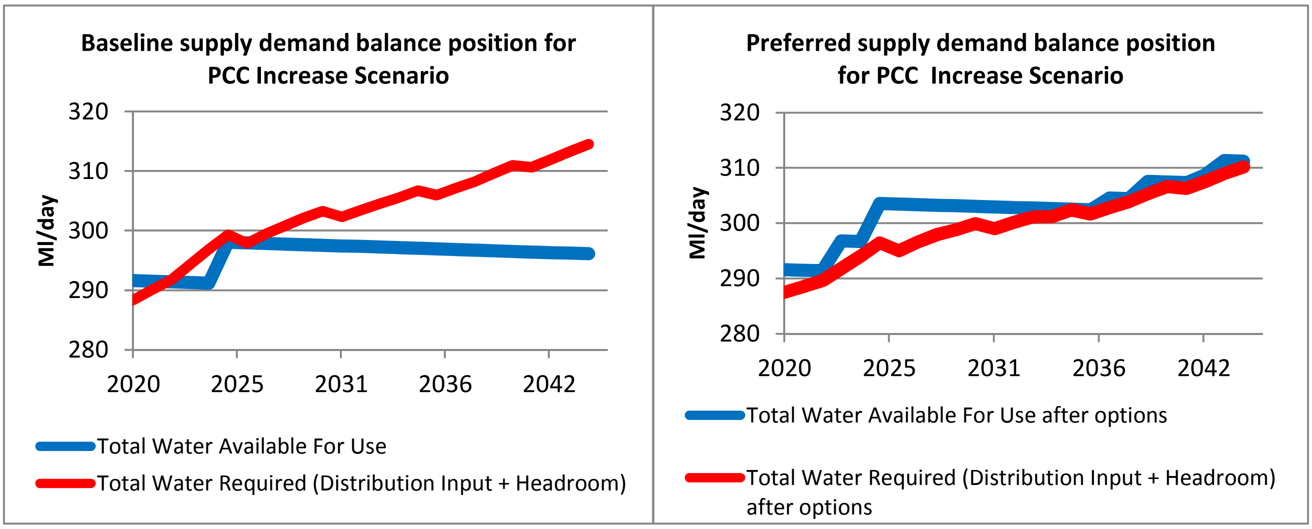
Figure 17-1: Supply-Demand Balance under Sustainability Reduction Scenario 1



17.3 Scenario 2: Sensitivity to Demand Forecast assumptions

This scenario assumes a 5% increase in PCC compared with the existing PCC forecast, leading to an increased demand of approximately 9.2 Ml/day by 2045. **Figure 17-2** demonstrates that the long-term supply-demand balance can be achieved in this scenario through reduction in leakage, raw water leakage reduction, implementation of drought management options at our Mendip Lakes sources during drought conditions and increase production for P01-02R WTW.

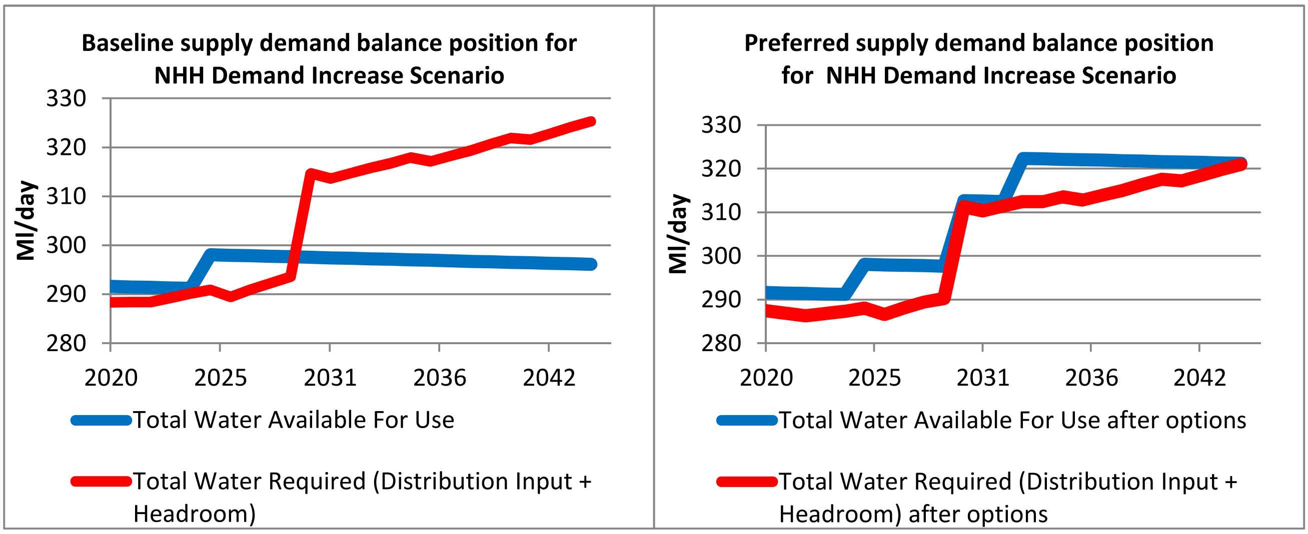
Figure 17-2: Supply Demand Balance on Demand Forecast Assumptions (Scenario 2)



17.4 Scenario 3: Sensitivity to increases in non-household demand

This scenario assumes a 20Ml/day increase in demand due to a large change to a non-household demand. In WRMP14 this was included in the final plan, based on projected demand resulting from a proposed power station at Avonmouth. As **Figure 17-3** demonstrates, the long-term supply-demand balance can be maintained in this scenario through reduction in leakage, raw water leakage reduction, implementation of drought management options at our Mendip Lakes sources during drought conditions, upgrade of our P01-02R treatment works, and purchase water form third parties.

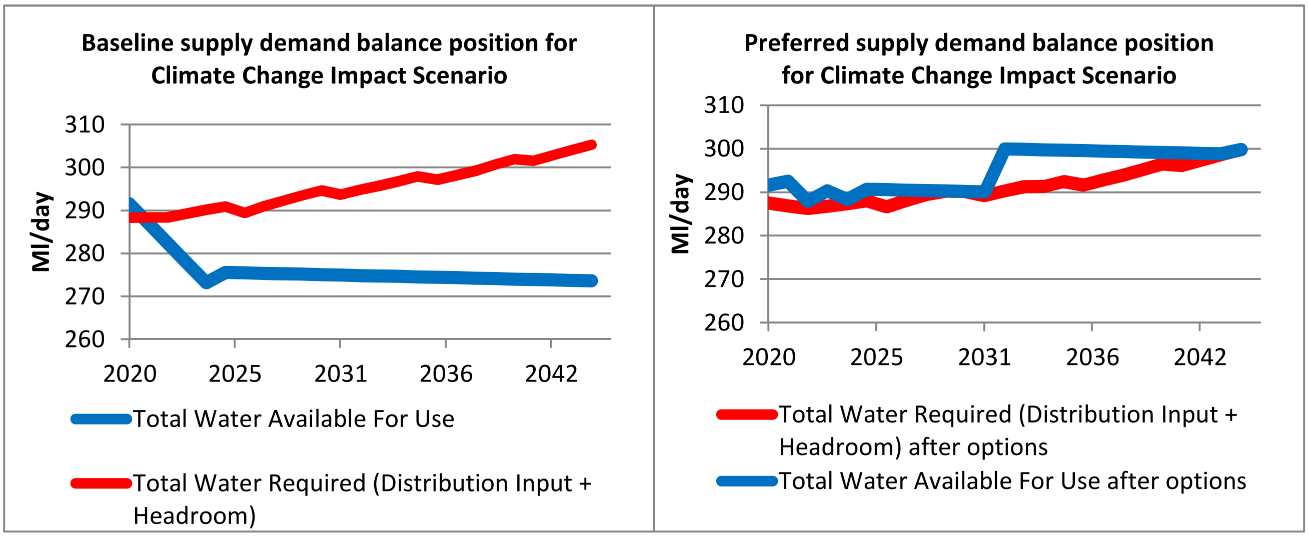
Figure 17-3: Supply demand balance- Increases in non-household demand (Scenario 3)



17.5 Scenario 4: Sensitivity to Climate Change assumptions

This scenario assumes a more extreme impact of climate change (25% probability) than assumed in our central estimate of climate change effects. This climate change impact is assumed from 2025. For the period 2020-2025 we assumed the linear increase of climate change impact to the point of simulated full climate change impact by 2025. As a result, it shows a supply deficit of almost 20 Ml/d in 2032 due to the reduced deployable output of water sources. This is a hypothetical scenario in the short-term but it could nevertheless be potentially possible in the longer-term. As **Figure 17-4** demonstrates, the long-term supply-demand balance under this extreme scenario can still be achieved through reduction in leakage, raw water leakage reduction, increased performance of P01-02R treatment works, and implementation of drought management options at the Mendip Lakes sources during the more frequent and more intense drought conditions. Enhanced promotion of free water meters to unmeasured households, and selective metering of domestic customers based on high consumption, would also be required. During the AMP9, 10 and 11 periods, additional water purchase from third parties would be required as well. At the very end of the planning horizon, modelling suggests that the introduction of new water sources within the Bristol Water CAMS area for the location R08-03R may be optimal.

Figure 17-4: Supply-demand balance under more extreme climate change impact assumptions



17.6 Scenario 5: Droughts worse than those in the historic record

The updated drought resilience assessment (**Section 6** and **10**) for the WRMP has shown that we are resilient to a 1 in 200 year drought event, which is a worse drought event than the worst historic drought. We have therefore not updated Scenario 5 that we carried out for the draft plan (at that time, we had not completed the drought resilience assessment work).

18 Future developments

Section Overview

We have determined that as part of our WRMP19 we will need to continue investment in improving our understanding of our customers, our water resources, our operations and our equipment. The environment in which we work is rapidly changing and, in the interests of meeting our customer needs and our business objectives, we need to keep increasing the focus and granularity of our data and information in particular areas. This section provides a brief outline of the improvements we have identified that will be beneficial in developing our future water resource management plans.

18.1 Introduction

Water resource planning is an iterative process that makes use of a steadily growing understanding of supply and demand for water. New technologies, changes in social behaviours around water use, climate change and environmental constraints mean that in order for long-term water management plans to be fit for purpose, we must both look long-term and address change through a responsive approach. In order to achieve this long-term view, and because planning for new supply options can take several AMP cycles, the planning horizon for a WRMP is always at least 25 years although the WRMP process is repeated within a five-year cycle.

During the development of our Plan, a number of opportunities for improvement to our technical methods and approaches have been identified for implementation in subsequent plans; these are detailed in **Section 18.2**.

Additionally, we will be looking for further innovation and data-sharing, including development of best practice water management options with our customers, stakeholders and other water companies in our region. This approach also involves working with a wider range of stakeholders than we have engaged in the past, to look beyond water as an isolated issue and bring it into a more central role as a keystone principle in work to drive affordability initiatives around energy, health and social resilience. We have already set up a new partnership called Resource West, seeking to bring together the key stakeholders in the West of England area to identify new approaches and partnerships that can help improve resource efficiency overall and show leadership for the West of England as a hub for green economic growth.

18.2 Future technical improvements to WRMP

Our current development and technical improvement plans are set out in the table below:

Technical area	Development/ Improvement proposals
Supply analysis	**Water Resource Modelling tools:** We will review our current water resource modelling tools in the context of current guidance and the alternative modelling options available for water resource management analysis to ensure that the models and analysis methods used for WRMP24 are reflective of the current regulatory

Technical area	Development/ Improvement proposals
	requirements and our business needs.
	Bathymetric surveys: We will use the information from our recently completed programme of bathymetric surveys on our reservoirs to ensure that the reservoir storage information used in our planning process is up to date and reflective of our current supply capacity.
	Inflow data review and update: We will review and update the catchment inflow data used in our water resource assessments. This will include, but not be limited to, an update of inflows to the latest outturn year.
	Reservoir control curve review: We will carry out a full review of our reservoir control curves in the context of the latest available information using our water resource modelling tools and updated data sets.
	Groundwater yield assessment: We will implement a programme of groundwater yield assessment to verify the current deployable output values reported for our groundwater sources.
	Climate change assessment: We are committed to improving our understanding of how climate change may affect our water resource position. We will therefore endeavour to be actively involved in any water industry research relating to climate change in order to maintain the latest assessment methods within our planning process.
Demand forecasting	**Bristol Water customers and micro-component information:** We are committed to look at the opportunities to develop the data and information relating to our customer base and their water use behaviours to support our demand forecast development. This would compliment the national data set approach that has been used to support this WRMP.
	Occupancy surveys: We are committed to looking at the opportunities to update our occupancy information via a programme of occupancy surveys to improve our understanding of our customer base.
	Water efficiency research opportunities: We are committed to our partnership project with UWE to help better understand the potential impact of water efficiency messaging on customer behaviour.
Levels of service	**Assessment of changes to levels of service:** We will continue to engage with our customers to understand their preferences in terms of levels of service they expect from us. Customer opinion on this issue could change in the aftermath of a drought and we will continue to investigate this area of customer research.
Sustainability reductions	**WINEP programme of work:** We are committed to completing any investigations required relating to the licences identified via the WINEP work to ensure our abstraction activity is sustainable in the long term. We will review any effect of the outcomes of this work on our resource position via the WRMP Annual Review process and the next update of our WRMP in 2024.
	Heavily Modified Water Body (HMWB) investigations: We are committed to working with the Environment Agency to implement solutions to managing the compensation flows from our HMWB reservoirs. We will continue to review and assess any potential effect (either positive or negative) this work may have on our water resource position.

19 National security and commercial confidentiallity

The published version of the final Water Resources Management Plan 2019 is required to exclude any matters of commercial confidentiality and any material contrary to the interests of national security. There were no matters of commercial confidentiality. In order to maintain the security of the water supply to our customer and in compliance with national security requirements as described in the Water Industry Act 1991 section 37(B) and the guidance provided by Defra in Advice Not 11 edition 5 "The Control of Sensitive Water Company Security Information" dated February 2016, some minor details have been removed (or redacted) from the Water Resource Management Plan documents we have published on our web site. This information is mainly about site names and we have also redacted a diagram of our water supply network.

Glossary of Terms

- **Abstraction:** The removal of water from any source, either permanently or temporarily.
- **Abstraction licence:** The authorisation granted by the EA to allow the removal of water from a source.
- **Abstraction point:** The top of a borehole for borehole abstraction; the river intake for a river abstraction to direct supply or bankside storage; the draw-off tower for a direct supply reservoir.
- **Annual average:** The total demand in a year, divided by the number of days in the year.
- **Available headroom:** The difference (in Ml/d or percent) between water available for use (including imported water) and demand at any given point in time.
- **Baseline forecast**: A demand forecast which reflects a company's current demand management policy but which should assume the swiftest possible achievement of the current agreed target for leakage during the forecast duration, as well as implementation of the company water efficiency plan, irrespective of any supply surplus.
- **Demand management:** The implementation of policies or measures which serve to control or influence the consumption or waste of water (this definition can be applied at any point along the chain of supply).
- **Deployable output:** The output of a commissioned source or group of sources or of bulk supply as constrained by: environment • Licence, if applicable • Pumping plant and/or well/aquifer properties • raw water mains and/or aquifers • transfer and/or output main • treatment • water quality
- **Distribution input**: The amount of water entering the distribution system at the point of production.
- **Distribution losses:** Made up of losses on trunk mains, service reservoirs, distribution mains and communication pipes. Distribution losses are distribution input less water taken.
- **Drought order:** An authorisation granted by the Secretary of State under drought conditions, which imposes restrictions upon the use of water and/or allows for abstraction/impoundment outside the schedule of existing licences on a temporary basis.
- **Drought permit:** An authorisation granted by the Environment Agency under drought conditions, which allows for abstraction/impoundment outside the schedule of existing licences on a temporary basis.
- **Dry year annual average unrestricted daily demand:** The level of demand, which is just equal to the maximum annual average, which can be met at any time during the year without the introduction of demand restrictions. This should be based on a continuation of current demand management policies. The dry year demand should be expressed as the total demand in the year divided by the number of days in the year.
- **Final planning demand forecast:** A demand forecast, which reflects a company's preferred policy for managing demand & resources through the planning period, after taking account of all options through economic analysis.
- **Final planning scenario:** The scenario of water available for use and final planning demand forecast which constitute the company's best estimate for planning purposes, and which is consistent with information provided to Ofwat for the Periodic Review.
- **Headroom:** is defined as "a planning allowance that a prudent water company should take into account when developing plans to balance supplies and demands and to deliver its

desired Level of Service". The allowance is called "target headroom" and is designed to cater for specified uncertainties in both demand side and supply side uncertainties.

- **Meter optants:** Properties in which a meter is voluntarily installed at the request of its occupants.
- **Micro-component analysis:** The process of deriving estimates of future consumption based on expected changes in the individual components of customer use.
- **Net Present Value:** The difference between the discounted sum of all of the benefits arising from a project and the discounted sum of all the costs arising from the project.
- **Non-households:** Properties receiving potable supplies that are not occupied as domestic premises, for example, factories, offices and commercial premises.
- **Outage:** A temporary loss of deployable output. (Note that an outage is temporary in the sense that it is retrievable, and therefore deployable output can be recovered. The period of time for recovery is subject to audit and agreement. If an outage lasts longer than 3 months, analysis of the cause of the problem would be required in order to satisfy the regulating authority of the legitimacy of the outage).
- **Raw water losses:** The net loss of water to the resource system, comprised of mains/aqueduct (pressure system) losses, open channel/very low pressure system losses, and losses from break-pressure tanks and small reservoirs.
- **Raw water operational use:** Regular washing-out of mains due to sediment build-up & poor quality source water.
- **Resource zone:** The largest possible zone in which all resources, including external transfers, can be shared and hence the zone in which all customers experience the same risk of supply failure from a resource shortfall.
- **Source:** A named input to a resource zone. A multiple well/spring source is a named place where water is abstracted from more than one operational well/spring.
- **Supply-demand balance:** The difference between water available for use (including imported water) and demand at any given point in time (c.f. available headroom).
- **Sustainability reduction:** Reductions in deployable output required by the Environment Agency to meet statutory and/or environmental requirements.
- **Target headroom:** The threshold of minimum acceptable headroom, which would trigger the need for water management options to increase water available for use or decrease demand.
- **Total leakage:** The sum of distribution losses arid underground supply pipe Losses.
- **Treatment work losses:** The sum of structural water loss and both continuous and intermittent over-flows.
- **WRP tables:** Water resources plan tables used for presenting key quantitative data associated with a water resources plan.
- **Water available for use:** The value calculated by deducting allowable outages and planning allowances from deployable output in a resource zone.
- **Water taken:** Distribution input minus distribution losses.

List of abbreviations

- **ADPW** Average day demand peak week
- **AISC** Average incremental social cost
- **CAMS** Catchment abstraction management strategies

- **Defra** Department for Environment, Food and Rural Affairs
- **DO** Deployable output
- **Ml/d** Megalitres per day Megalitres = one million litres (1,000 cubic metres)
- **Ofwat** The Water Services Regulation Authority
- **ONS** Office for National Statistics
- **PCC** Per capita consumption - consumption per head of population
- **UKWIR** United Kingdom Water Industry Research Limited
- **WAFU** Water available for use
- **WCA** Water Companies Association
- **WRP** Water resources plan
- **WSA** Water Services Association
- **Water UK** Water UK (formerly known as the Water Services Association)

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