Water Resources Management Plan

Yorkshire Water Services Ltd

April 2020

ADDENDUM

Our Water Resources Management Plan 2019 (WRMP19) was produced and first published in draft format in 2018 prior to water companies receiving determination from Ofwat on their 2019 Business Plans. Our draft plan included an ambitious leakage reduction programme to reduce the 2019/20 regulatory leakage target of 287Ml/d by 40%. It also included an alternative scenario to achieve a 15% reduction of the 2019/20 leakage target by 2025. This lower scenario will deliver demand reduction of 43Ml/d, which is greater than the forecast deficit of 34Ml/d by 2044/45.

In order to meet our draft WRMP2019 target we set a company target to achieve a significant initial reduction, that would take us beyond our regulatory leakage targets in 2018/19 and 2019/20. Despite our best efforts to achieve this, we did not meet the company target in 2018/19. We experienced a drought in 2018 and the prolonged period of hot dry weather led to unprecedented ground movement, which caused significantly more leaks than we would normally experience.

The additional leakage resources we employed in 2018 meant we met our regulatory target in this exceptional year, which we would not have done without the extra effort. However, it also meant that we needed to revise our ambition to achieve a 40% reduction by 2025. We therefore proposed an alternative leakage programme to achieve a 40% reduction by the 2nd year of AMP8. This included a challenging target of 269Ml/d in 2019/20 and year on year reductions to achieve a reduction that is 25% of 269Ml/d by 2025.

Defra agreed to this change to the leakage target and directed us to publish our WRMP19 incorporating leakage targets as summarised above.

The success of our ambition was dependent on Ofwat granting enhanced funding for additional leakage activity from 2020 to 2025. Since receiving permission to publish our WRMP19 we have received the Final Determination for our 2019 Business Plan. Ofwat has stated it has an expectation for all water companies to achieve stretching leakage performance commitments from their base allowances, not from

enhancement expenditure. We therefore do not have any additional funding for the activity required to achieve our leakage reduction target over the next five years.

The Ofwat final determination set us a leakage performance commitment to achieve a 15% leakage reduction between 2020 and 2025. This target is a three-year rolling average target and will be 15% of average actual leakage as reported for 2017/18, 2018/19 and 2019/20. The target is to be achieved through our base allowance from Ofwat. If in any year we achieve a leakage level beyond our leakage performance commitment, we will receive an out-performance reward.

During the AMP7 period we will be working hard to meet all our performance commitment targets and will continue to introduce new and innovative measures for achieving leakage reduction. This does create some potential for us to reduce leakage beyond our performance commitment levels and, in accordance with Defra's direction, we have published our WRMP19 with a higher leakage ambition than our Business Plan 2019 performance commitment.

If our WRMP19 leakage target is not met this does not pose a risk to our supply demand balance as our leakage performance commitment target will close the deficit. We will be reporting our leakage performance to our regulators at the end of each financial year and will also report progress on delivering our WRMP19 by submitting an annual review to Defra and the Environment Agency on the anniversary of its publication.

Executive Summary

About our Water Resources Management Plan

Our Water Resources Management Plan 2019 (WRMP19) is one of the key plans that will help us to ensure that our customers get what they have told us is their highest priority – a reliable and sustainable supply of good quality, clean water. The plan describes how we will ensure that we continue to have sufficient water to supply our customers, in the face of future challenges such as climate change, population growth and environmental pressures.

In Spring 2018 we published our draft WRMP19 for consultation. Following this consultation, we published a Statement of Response and a revised plan in September 2018, taking into account representations received from stakeholders and consultees. Since publishing our Statement of Response, we have made further changes to the WRMP19 to adjust the implementation of our future leakage activity and to include a proposal to increase a river abstraction licence that will provide additional winter resilience.

Our WRMP19 provides a long-term view of our future challenges, planning for the next 25 years. We have also extrapolated data to give us a prediction as to what our water resources situation could be in 40 years' time; although the further into the future we project, the greater the uncertainty.

The requirement for Water Resources Management Plans to be published every five years is set out in the Water Industry Act 1991. It is therefore a well-established and mature part of our business planning process. As with previous plans, our WRMP19 has been prepared in line with guidance that is provided by the Environment Agency. In addition, there are numerous other well documented approaches that we take to build individual components of the plan – for example, UKWIR methods for calculating water resources yield, and guidance on how to take a risk-based approach to planning.

What challenges do we face?

Yorkshire Water already has one of the most resilient water resource systems in the country. There are a number of reasons for this. Firstly, our grid network allows us to move water around Yorkshire to help balance supply with demand. Secondly, we take our water from a variety of different types of water supply, balancing across reservoirs, rivers and groundwater sources. Thirdly, we plan for extreme droughts that go well beyond those that we have experienced in our historical record.

This level of resilience was recognised by the independent work carried out for Water UK's *Water Resources Long Term Planning Framework* report, published in late 2016, which stated:

- Yorkshire Water "now plans to a higher level of resilience than any other part of the country"; and,
- Yorkshire Water is one of only two companies that "plan for resilience to droughts that are worse than those seen in the historic record".

Further, the report's independent modelling validated our own assessment of the resilience of our water supply system.

However, despite our current high level of resilience, we cannot afford to be complacent at a time where the world around us is changing. With an increasing population, uncertainty about our future climate, and our customers rightly expecting more from us, we need to continue to evolve our plans. We need to be innovative and ambitious, whilst at the same time recognising the importance of security and resilience when planning for water resources.

In addition, our customers remain concerned about affordability now and into the future. We need to find ways of addressing the pressures we face in the future through a changing climate, population growth and environmental protection without causing customers' bills to become unaffordable.

The key challenges that our WRMP19 has identified, and addresses, are:

- a Yorkshire population that is projected to increase by one million by 2045;

- a projected loss of 100Ml/d supply by 2045, due to climate change;
- ongoing environmental pressure to reduce the amount that we abstract; and,
- ensuring that we can continue to provide high levels of resilience and meet our agreed levels of service, against a backdrop of maintaining bills at a level that is affordable for all our customers.

How have we created our plan?

Our WRMP19 shows how we will balance the demand for water and the available supply of water in the short, medium and long term, projecting up to 40 years into the future. It is built up from two key components – a demand forecast, and a supply forecast. These forecasts are compared to identify whether, or when, we may have a deficit. A deficit occurs when, in a dry year, the forecast demand (plus an allowance for headroom) exceeds the forecast supply.

If, or when, we reach such a position, the plan identifies potential options to address the forecast deficit. A 'twin track' approach is used, looking at ways of reducing demand whilst also exploring options for increasing supply. It is not acceptable, or sustainable, to simply plan to extract more water from the environment.

Our WRMP19 covers the two water resource zones which make up the Yorkshire Water region. These zones are the Grid Surface Water Zone, which covers over 99% of our customers, and the East Surface Water Zone, which is a small area covering Whitby and part of the North York Moors National Park.

Supply forecast

We have worked closely with the Environment Agency to understand where environmental pressures may reduce the amount of water available to us in the future. We will continue to investigate areas that may be affected by reduced abstraction, to ensure that we balance environmental needs with the requirement for maintaining service resilience.

We have updated our assessment of the impact of our changing climate on water resources. Customers have told us that they want to see clear plans for managing the challenges presented by climate change.

We have also considered how water quality may change in the future, and how we will need to invest in a range of solutions to ensure that we do not compromise on the quality of water supplied to customers. We will continue to work closely with landowners, land managers and the agriculture sector to enhance the resilience of our raw water sources, as the first stage in the journey of ensuring water quality from source to tap. We have ensured that our WRMP19 is aligned with the requirements of our drinking water quality regulator, the Drinking Water Inspectorate.

We have also considered how we might need to respond to the risk of invasive non-native species, and the risks that these may present to current and future water transfers between catchments. We have been working closely with the Environment Agency, and other organisations including the University of Leeds, to understand this risk and how best it can be mitigated.

The key components of our supply forecast, and a summary of how these components have changed since our last plan, are shown in Table 1 below. However, because climate change is the component that has the biggest single impact on our future supply forecast, and because our climate change forecast has changed since WRMP14, we have also included below some more detailed commentary on climate change.

Climate change

Our last plan (WRMP14) projected that we would have a supply demand deficit (against headroom, in a dry year) by 2018/19. Our WRMP19 shows that we now do not expect to see this deficit before the mid-2030s. One of the key reasons for this difference is that our approach to climate change has changed.

The three most significant changes are:

- In WRMP14 we used UK Climate Projections 2009 (UKCP09) medium emissions forecasts to the 2030s. However, the Environment Agency

guidelines on which forecasts to use have now changed so for the WRMP19 we are using forecasts to the 2080s.

- As in WRMP14, we are using 20 selected climate change model scenarios (out of 10,000 that are included in the UKCP09 dataset). For WRMP14 we analysed the data and selected 10 low probability dry scenarios and 10 from across the whole range of climate change projections. We modelled these 20 scenarios and used the median. For our WRMP19 we again carried out an intermediate vulnerability assessment and based on this selected 20 from across the whole range of scenarios, using statistical sampling stratification to get a representative sample. We also included three dry scenarios in our assessments.
- In WRMP14 we used the Environment Agency scaling equations. In this plan, we are not using the new Environment Agency scaling equations but are instead following guidance and using an alternative interpolation (similar to that used in 2014, but with a less steep initial gradient). We are doing this because using the current Environment Agency scaling gives a loss of about 70Ml/d by year 1 of AMP7 (2020/21), which we do not believe to be a likely scenario in Yorkshire. We have discussed this approach with the Environment Agency and with our external auditor, and both agreed that a decrease of 70Ml/d by 2020/21 was unlikely.

Although we are showing a reduced impact of climate change in WRMP19 compared to WRMP14, climate change remains the biggest single influence on our long-term future water resources prospects. A new set of climate projection data for the UK (UKCP18) was published in 2018. To ensure that we understand what this new data is telling us, we have represented the UK Water Industry on the UKCP18 users' group, and we are leading work looking at how the UK water industry will use this latest evidence for future planning.

Table 1 Summary of supply forecast and key changes since WRMP14

Component	Summary for WRMP19	WRMP14 position
Climate change	Loss of 100Ml/d of deployable output in the Grid SWZ by 2044/45.	Loss of 127.5Ml/d of deployable output in the Grid SWZ by 2035/36, and 136.0 Ml/d by 2039/40.
WINEP / sustainable abstractions (impact only for first 5 years of planning period)	Loss of 1.5Ml/d yield by 2024.	Loss of 2.7Ml/d yield by 2020.

Our modelled deployable output includes an existing import from Severn Trent Water. The import provides a raw water source (approximately 50Ml/d) to a single water treatment works in the south of our region from the Derwent Valley reservoirs in the Severn Trent Water region. The bulk transfer agreement for this import terminates in 2085, with an early 'break clause' which allows termination by either party from 2035 following a 5-year notice period. In their draft WRMP, Severn Trent Water included a 15Ml/d reduction in the import volume from 2030 in their best value plan. Severn Trent Water has subsequently confirmed that they no longer require a reduction in our import in 2030. We have committed to work together to investigate options for varying the agreement in the wider context of the Water Resources North Group. This joint work will involve water resources modelling of the Derwent Valley system and developing options for the Derwent Valley and wider Yorkshire Water and Severn Trent Water systems.

To help us understand what the future demand for water may be, we have updated our projections of population increase in Yorkshire. We have also considered how we can help to reduce the amount of water that gets used both by our customers and through our own operations. Our customers have clearly told us that they want

us to reduce how much water is wasted through leakage, and in response to this we have set ourselves ambitious targets for leakage reduction.

The key components of our demand forecast, and how these components have changed since our last plan are shown in Table 2 below.

Table 2 Summary of demand forecast and key changes since WRMP14

Component	Summary for draft revised WRMP19	WRMP14 position
Household demand – population	Latest projections indicate population of Yorkshire at 6.4 million by 2040, up one million compared to 2016.	Increase in forecast population growth, from 850,000 in last plan.
Household demand – new properties	Up to 578,000 more properties to be served, taking total number up to 2.85 million.	Up to 500,000 new properties.
Non-household demand	A projected continued slow decline in non-household demand, amounting to 18Ml/d over the 25-year plan, driven mainly by reduced non-service sector demand.	Slow decline over plan period, 28Ml/d reduction over the 25-year plan.
Leakage	Targeting a reduction in leakage of 40% from the end of AMP6 to AMP9.	Reduction of 47Ml/d over 25-year planning period, to 250Ml/d by 2040.

The overall impact of the above is that we are forecasting that demand will reduce in the early years of the planning period. There are three main reasons for this:

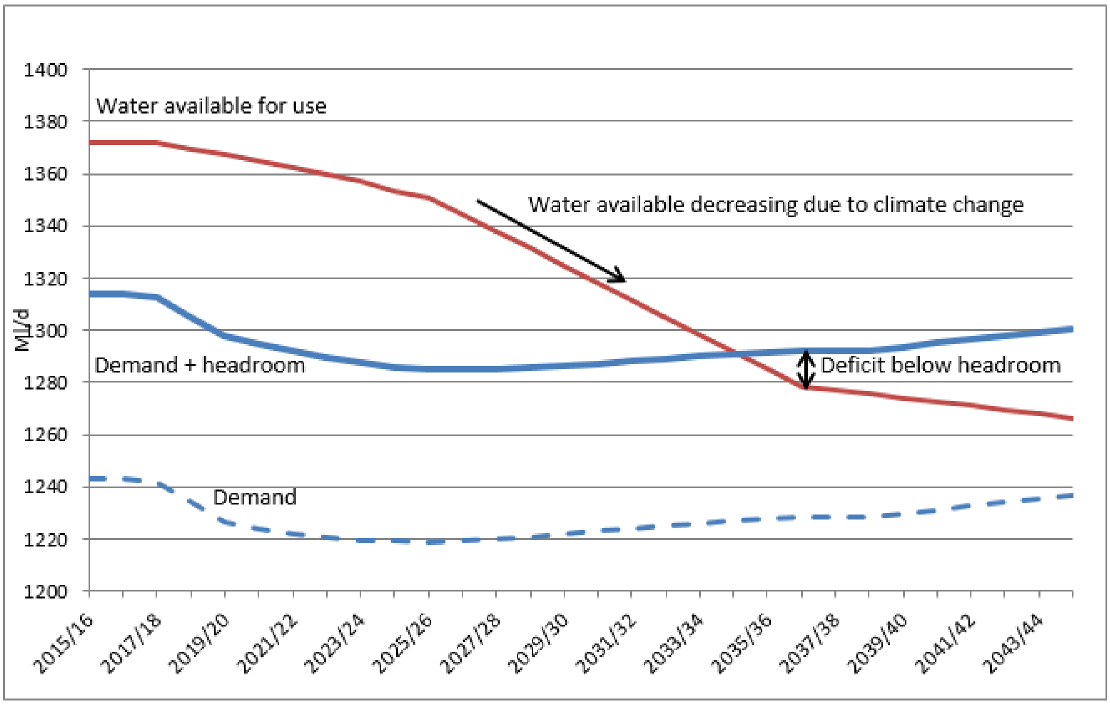
- a continued reduction in leakage for the remainder of AMP6 and into AMP7 and beyond;
- ongoing reduction in household usage due to increased levels of metering; and
- reduced non-household demand due to a continued decline in industrial (non-service sector) use.

After stabilising in the late 2020s, we are forecasting that demand will increase for the remainder of the planning period up to 2045. This increase is due to the impact of population growth, as well as decreasing numbers of customers opting for a metered supply.

What is our projected supply demand balance?

Our forecast supply demand balance to 2045 is shown in Figure 1 below. This is our baseline, with no significant additional leakage reduction, or other investment activity, included.

Figure 1 Baseline supply demand forecast



This baseline shows that we are currently in surplus, and that we expect that this will continue to be the case until the mid-2030s. After that point, we begin to show a deficit below headroom.

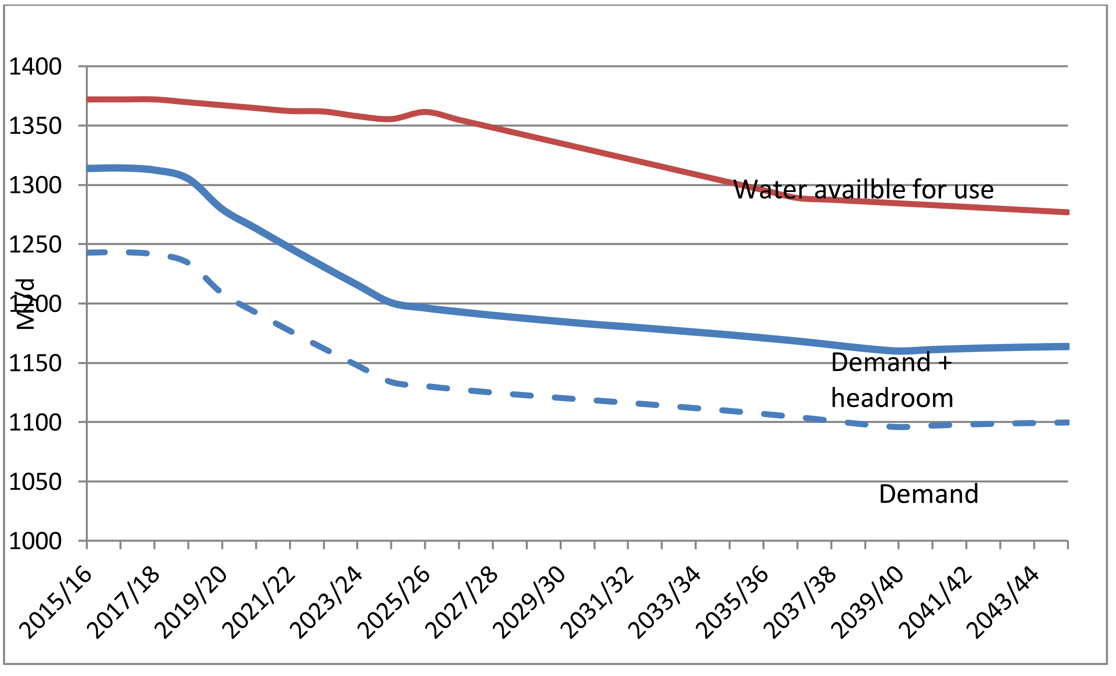
What is our preferred solution?

Although we are not expecting a deficit in our supply demand balance until the mid-2030s, we still need to plan activity and investment that will address the forecast deficit. We also need to ensure that we maintain resilience in our water resources position; we would not want to wait until the deficit appears before taking action.

In addition, we recognise that we have a responsibility to continue to reduce leakage, and our preferred solution therefore includes a proposed 40% reduction in leakage by AMP9. Our forecast supply demand balance to 2045 for our preferred solution is shown in Figure 2 below. This shows that with the proposed leakage reduction we do not expect to see a supply / demand deficit at any point during the planning period.

Our preferred solution also includes proposed investment in some of our borehole supplies to enhance our resilience to risks associated with headroom and outage.

Figure 2 Preferred solution supply demand forecast



Summary

Our WRMP19 indicates a risk of a deficit during the 25-year planning period beginning 2034/35. This is predominantly due to the forecast impact of climate change on deployable output. However, the predicted impact is less extreme than WRMP14 due to a change in the forecasting methodology, and to reflect the fact there has been no reduction in supply due to climate change this AMP. Increased demand management activity, including additional leakage reduction, also reduced the deficit.

For our preferred solution to meet this forecast deficit, we have chosen to reduce leakage by 40% by AMP9. In addition to this leakage reduction activity, we will investigate two supply options to provide additional resilience. The supply options are scheduled for implementation in 2022/23 and 2025/26, provided the results of the investigations determine that the abstraction licences are sustainable. We have also included a proposal to increase a river abstraction licence that will provide additional winter resilience and a potential increase to a groundwater abstraction as an alternative to a clean water network scheme included in our Business Plan 2019.

In selecting our preferred plan, we have chosen a solution that minimises environmental risks, meets customer and regulatory preferences and is flexible and sustainable in an uncertain future. This is in line with the needs we, our customers and our stakeholders identify as priorities in our new long-term strategy for Yorkshire Water.

We believe that our WRMP19 will help us to ensure that customers continue to get what they prioritise highest – a reliable and sustainable supply of clean water. Our plan also shows that we can maintain our current high levels of water resources resilience into the future, helping to ensure that bills remain affordable. Other activities that our customers consider to be important, such as reducing leakage, will help to contribute to our sustained resilience.

In addition, recognising that we have a role to play in supporting not only the resilience of our region, but also the resilience of the UK as a whole, in late 2017 we took a lead in setting up Water Resources North. This group, which covers the area served by Yorkshire Water, Northumbrian Water and Hartlepool Water, will provide

a focal point for co-ordinating water resources across all sectors, in support of the new Water Resources National Framework and in co-ordination with the four other regional groups that exist in other parts of the country. It will also allow for integrated and consistent consideration of the opportunities that we collectively have available to transfer water to other parts of the country and contribute to enhanced national water resilience.

Contents

1 Introduction

This section describes why we need to prepare a Water Resources Management Plan. It identifies that, although we currently have a high level of water resources resilience, we still face some challenges. This section goes on to outline the work that we have completed to inform our plan and identify how it supports us in ensuring that we provide what our customers want. Finally, it references relevant Government policy and regulator guidance that has supported our approach to our plan.

1.1 Overview of our Water Resources Management Plan

Water companies are required to produce a Water Resources Management Plan (WRMP) every five years. Our WRMP sets out our plans to maintain a balance between supply and demand for the minimum statutory 25-year period from 2020 to 2045. However, to help ensure that we are planning for the long-term resilience of water supply to our customers, we have also looked at the potential supply demand balance for 15 years beyond this period, up to 2060. The plan considers how issues such as population growth and climate change may alter future demand for water in Yorkshire, as well as the supplies that are available to us.

In Spring 2018 we published our draft WRMP19 for consultation. Following this consultation, we have revised our plan, taking into account representations received from stakeholders and consultees. Since publishing our Statement of Response, we have made further changes to the draft WRMP19 to adjust the implementation of our future leakage activity and to include a proposal to increase a river abstraction licence that will provide additional winter resilience. These further changes are highlighted grey.

Our previous WRMP was published in 2014 and will be superseded by this new plan.

We have prepared this plan in accordance with the *Water Resources Planning Guideline* (Environment Agency and Natural Resources Wales, 2017) and *Guiding principles for water resource planning* (Defra, 2016). These guidelines define the methods that we use for estimating the components of supply and demand that inform our plan.

Our plan also identifies how we will take a twin track approach to ensure that we maintain a resilient balance between demand and supply into the future. The twin track approach recognises that both demand management (reduction) measures and additional supply (new resource) options have a role to play in maintaining a water supply balance. It is not acceptable to simply abstract more water from the environment; we must also work to reduce the amount of water used by ourselves and by our customers.

The WRMP19 demonstrates how we will maintain the levels of service that we have agreed with our customers, and specifically how we will maintain our minimum level of service of no more than one Temporary Use Ban (TUB, formerly known as hosepipe bans) in 25 years, or a 4% risk of occurrence in any year, in line with our draft Drought Plan 2018.

1.2 What challenges do we face?

We have one of the most resilient water resource systems in the country. Firstly, our grid network allows us to move water around Yorkshire to help balance supply with demand. Secondly, we take our water from a variety of different types of water supply, balancing across reservoirs, rivers and groundwater sources. Thirdly, we plan for extreme droughts that go well beyond those that we have experienced in our historical record.

This level of resilience was recognised by the independent work carried out for the *Water Resources Long Term Planning Framework* (Water UK, 2016) report, which stated:

- Yorkshire Water "now plans to a higher level of resilience than any other part of the country"; and

- Yorkshire Water is one of only two companies that "plan for resilience to droughts that are worse than those seen in the historic record".

The report's independent modelling validated our own assessment of the resilience of our water supply system.

However, despite our current high level of resilience, we cannot afford to be complacent at a time where the world around us is changing. With an increasing population and uncertainty about our future climate, and with our customers rightly expecting more from us, we need to continue to evolve our plans. We need to be innovative and ambitious, whilst at the same time recognising the importance of security and resilience when planning for water resources.

In addition, our customers remain concerned about affordability now and into the future. We need to find ways of addressing the pressures we face in the future through a changing climate, population growth and environmental protection without causing customers' bills to become unaffordable.

The key challenges that our WRMP19 has identified, and addresses, are:

- a Yorkshire population that is projected to increase by one million by 2045;
- a projected loss of 100Ml/d supply by 2045, due to climate change;
- ongoing environmental pressure to reduce the amount that we abstract; and
- ensuring that we can continue to provide high levels of resilience and meet our agreed levels of service, against a backdrop of maintaining bills at a level that is affordable for all our customers.

1.3 What have we done to inform our WRMP?

To help us understand future demand for water we have updated our projections of population in Yorkshire. We have also considered how we can help to reduce the amount of water that gets used both by our customers and through own operations. Our ambition is to reduce how much water is lost through leakage, and we will be setting ourselves challenging targets for leakage reduction.

On the supply side, we have worked closely with the Environment Agency to understand where environmental pressures may reduce the amount of water available to us in the future. We have also updated our assessment of the impact of our changing climate on water resources.

We have considered how water quality may change in the future, and how we will need to invest in a range of solutions to ensure that we do not compromise on the quality of water supplied to customers. We will continue to work closely with landowners, land managers and the agriculture sector to enhance the resilience of our raw water sources, both in terms of volume and water quality.

In developing our plan, we have thought about how as a company we impact on Yorkshire's environment, its economy and people as we carry out our activities. As well as talking to our customers to find out their priorities, we have engaged expert assistance to provide us with the latest understanding of the challenges that we face.

1.4 What are our customers telling us?

Since 2015 we have held nearly 30,000 customer conversations. This has helped us understand more about what is important to our customers now and in the future. We have talked to our customers about how water plays a part in their lives and the dependencies that we all have on water. These conversations have helped us to develop our long-term strategy, which was published in March 2018.

As part of our last strategy review in 2013, customers told us their priorities for the next 25 years. This led to key outcomes for Yorkshire Water and a series of performance commitments against which we measure ourselves.

Customers are now telling us that their priorities remain the same, but they want us to deliver them in different ways. We therefore need to change the way we work so that we can continue to meet our customers' expectations.

Our customers have clearly told us that their number one priority is a reliable supply of clean, good quality, water. They need to know that their water supply is secure, wholesome and sustainable. Our customers also want us to stop failures in service

from affecting their lives. We need to ensure that our water supply system is resilient.

Our customers have also told us that they want us to waste less water through leakage. Throughout discussions with our customers a key message was the need for us to demonstrate where and how we will go above our standard duties and encourage customer support by showing that we are ‘doing our bit’. We received a clear message that we cannot expect our customers to embrace changes in their own water use if they do not see a change in our approach to leakage.

We know that our customers are concerned about climate change. They want to know that we have clear plans in place for how we intend to manage climate change challenges. Our customers also remain concerned about affordability.

Currently we provide approximately five million customers with water. Our latest forecasts indicate that we may need to supply an additional one million customers over the next 25 years. We need to know that we can continue to supply not only our existing customers, but also those new customers who will join us in the future.

To reflect our customers’ priorities and ensure that we can deliver against the challenges outlined above, we have set out five goals in our new long-term strategy. Our water supply goal states that “we will always provide our customers with enough safe water; we will not waste water and we will always protect the environment”.

Our WRMP19 is one of the key components that will help us to deliver this goal. We will start by looking at ourselves, the water that we use, and the water that is lost through leakage. We have set ourselves ambitious leakage reduction targets and will be using innovative new techniques to help us drive down the cost of identifying and repairing leaks. We will also continue to work closely with our customers to make sure that we all have enough water without increasing our demands on natural resources.

Our WRMP19 describes how we will ensure that we continue to have sufficient water to supply our customers, in the face of climate change, population growth and environmental pressures.

This plan ensures that we will continue to provide our customers with a secure water supply that meets demand both now and in the future.

Full details of our engagement with customers for business planning and the draft WRMP19 are provided in Appendix C.

1.5 What are our regulators telling us?

In the lead-up to the publication of our draft WRMP19, Defra and our regulators published a series of guidance documents. In summary, these set out expectations to secure the long-term resilience of water supplies because of climate change and an increasing population. The focus has been on environmental protection and innovation in the form of markets, trading between companies, demand management and the active involvement of our customers, for instance, in setting levels of service as well as demand management options. Overall the guidance documents promote a WRMP that is longer-term in its perspective and fully embedded in company business planning.

In *Creating a great place for living. Enabling resilience in the water sector* (Defra, 2016), Defra noted that climate change, through changing weather patterns such as higher summer temperatures and lower summer rainfall, and population growth pose long term challenges on the water sector in England. This is because both impact on the balance of water supply and the customer demand for water.

The Defra document set out a policy road map to adapt to climate change which has continued through the *UK Climate Change Risk Assessment* (Committee on Climate Change, 2017), and we anticipate the 2018 National Adaptation Programme will encourage coordinated activity.

In response, the water industry published *Water Resources Long Term Planning Framework* (Water UK, 2016) to look at our water needs over the next 50 years, and the strategic options that could meet these needs. It noted additional drivers of a growing economy, environmental pressures on abstraction and that future droughts maybe more severe than those experienced to date and sought to improve coordination of resilience across the country.

In tandem, Ofwat has evolved its regulatory framework in line with its new duty to further the long-term resilience of the water sector, to take account of the long-term challenges posed by climate change, population growth and changes in consumer behaviour.

Delivering Water 2020: Consulting on our methodology for the 2019 price review (Ofwat, 2017) sets expected improvements in long-term water planning for PR19. These included the integration of the development of our WRMP into our business planning and referenced previous Ofwat guidance. This previous guidance emphasised the need to clearly set out the outcomes we plan to deliver for our customers, the resilience of supplies, the risks to delivery of those outcomes and evidence that we have considered the full range of options for mitigating those risks. We anticipate the guidance to be consolidated in the final Ofwat 2019 price review methodology.

The Government's strategic priorities and objectives for Ofwat (Defra, 2017) sets out Defra's priorities for Ofwat and the water industry in two overarching priorities:

- securing long-term resilience: Customers expect resilient services, now and in the future – but some regions are exposed to substantial risks from service failures, for example due to drought; and
- protecting customers: Every home and business depends on a resilient water industry – but not everyone can afford their water bill.

The document included a third priority: Ofwat should promote markets to drive innovation and achieve efficiencies in a way that takes account of the need to further: (i) the long-term resilience of water and wastewater systems and services; and / or (ii) the protection of vulnerable customers.

The *Guidance Note: Long term planning for the quality of drinking water supplies* (Drinking Water Inspectorate, 2017) which requires our WRMP19 to take account of all statutory drinking water quality obligations, and to include plans to meet their statutory obligations in full.

The Water industry strategic environmental requirements (WISER) Strategic steer to water companies on the environment, resilience and flood risk for business planning

purposes (Environment Agency and Natural England, 2017) sets out the obligations and expectations for the water industry during the price review period 2020 to 2025 (PR19). It provided further security of supply guidance on resilience, demand measures, leakage, drought management, future sustainability changes and protecting the environment.

Following preparation of our draft WRMP19 the Government published *A Green Future: Our 25 Year Plan to Improve the Environment* in January 2018, which sets out their plans to improve the environment within a generation. Within this plan are goals and targets for water management, with the aim of achieving clean and plentiful water by improving at least three quarters of waters to be close to their natural state as soon as is practicable.

The plan sets out how this will be achieved through a number of goals including:

- reducing the damaging abstraction of water from rivers and groundwater, ensuring that by 2021 the proportion of water bodies with enough water to support environmental standards increases from 82% to 90% for surface water bodies and from 72% to 77% for groundwater bodies;
- reaching or exceeding objectives for rivers, lakes, coastal and ground waters that are specially protected, for biodiversity or drinking water as per River Basin Management Plans; and
- supporting Ofwat's ambitions on leakage, minimising the amount of water lost through leakage year on year, with water companies expected to reduce leakage by at least an average of 15% by 2025.

The National Infrastructure Commission published its *National Infrastructure Assessment* in July 2018. The report included proposals to ensure resilience to extreme drought through additional supply and demand reduction, to minimise the impact of severe weather and climate change and reduce the risks of drought and flooding.

The Commission also published a stand-alone report *Preparing for a drier future: England's water infrastructure needs* in April 2018. This sets out a twin-track approach to manage water supply and demand through increased water supply

system capacity, managing demand and reducing leakage. The report suggests that this could be achieved through: delivering a national water transfer network and additional water supply infrastructure by the 2030s; halving water lost through leakage by 2050 and reducing customer demand through smart metering.

Most recently, Defra, the Environment Agency, the Drinking Water Inspectorate and Ofwat sent a joint letter to water companies in August 2018, setting out requirements to build resilience in water resources management in England. The letter describes how ambitious and co-ordinated leadership across industry, government and regulatory bodies is needed to meet this challenge. It sets out requirements for water companies including greater ambition in areas such as demand management (leakage and customer water use), coordinated water resources planning and use of competition and markets.

Following the August 2018 letter, the Environment Agency has been working with regional groups and other stakeholders to develop a national framework for water resources. This work, which we are supporting through Water Resources North, will deliver its first report in late 2019. We will continue to engage proactively with this work to ensure that we are contributing to the development of the national framework and are fully informed as to how this national work will need to be considered during the next round of WRMP in 2024.

Our WRMP19 has addressed the priorities of the Government and our regulators to ensure we can continue to meet the needs of people, businesses and the environment of Yorkshire.

1.6 The Capitals

We are embedding the concept of the Capitals into our long-term business planning, to help us ensure the affordability and resilience of our essential public services for current and future generations. The Capitals are the valuable assets which are critical to the success of any organisation, and effective management of the Capitals helps ensure the resilience of our business. We consider the six capitals illustrated below: Financial, Manufactured, Natural, Social, Human and Intellectual capital.

We are continuing to develop our approach to the Capitals as a part of our PR19 Business Planning process. Therefore, while our WRMP19 has been based on a traditional approach to monetising environmental and social impacts when determining our solution, we are currently planning to carry out a more holistic assessment of the Capitals for future plans.

2 Developing our plan

This section describes how we have developed our revised draft WRMP19. It details our water resource zones and the scenarios that we plan for in each zone. This section also summarises how we have followed technical guidance in our problem characterisation and risk composition processes. Finally, this section explains the levels of service that we have agreed with our customers.

2.1 The WRMP process

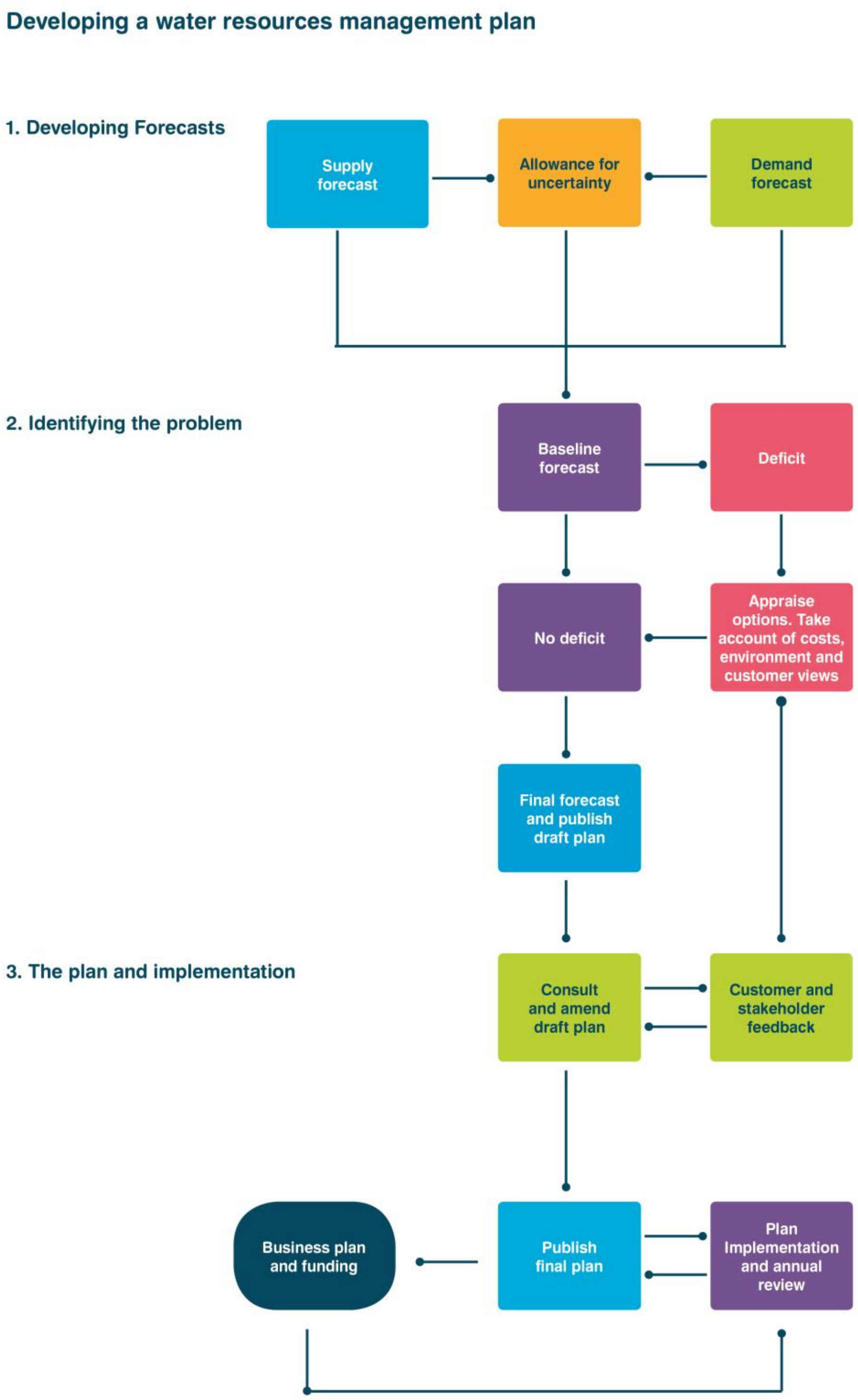
The process that we have used to prepare our WRMP19 is shown in Figure 2.1. This shows that we build forecasts for both supply and demand for each of our water resource zones, and that we recognise that there is uncertainty inherent in these forecasts. We compare our forecasts for supply and demand and identify whether these forecasts are in balance or not, for the whole duration of the planning period. This is our baseline forecast.

If our baseline supply and demand are not in balance, we consider that we either have a deficit (if demand is predicted to exceed supply) or a surplus (if supply is predicted to exceed demand). If our supply demand balance shows a deficit, we need to identify and assess options to offset that deficit. Taking a twin track approach, some of the options that we consider involve reducing demand, and some of them look at increasing supply.

Once we have assessed all the options that are available to us, taking into account factors such as environmental impact and cost, we are able to identify our preferred solution. We can then produce our final forecast.

When we have our final forecast in place, we prepare our draft WRMP19. This is published for consultation and, where appropriate, amended based on the feedback that we receive. We then publish our final WRMP19, ensuring also that it aligns with our PR19 Business Plan.

Figure 2.1 Development of the water resources management plan



2.2 Our water resources zones

This plan covers the two water resource zones which make up the Yorkshire Water region. Our zones are:

- the Grid Surface Water Zone (Grid SWZ), which is an integrated surface and groundwater zone that makes up over 99% of our supply area; and
- the East Surface Water Zone (East SWZ), which is a small zone covering Whitby part of the North York Moors National Park.
-

Figure 2.2 Water resource zones

2.3 Water resource zone integrity

In *Water Resources Planning Tools*, (UKWIR, 2012), a water resources zone is defined as:

"The largest possible zone in which all resources, including external transfers, can be shared and hence the zone in which all customers will experience the same risk of supply failure from a resource shortfall."

The Environment Agency has published guidelines on ensuring the integrity of water resource zones, *Water resource zone integrity, (*Environment Agency, 2016*)*. These guidelines include pro formas for decision trees to establish if a resource zone complies with the Environment Agency definition.

The pro formas for the Grid SWZ and the East SWZ are shown in Appendix A of the Deployable Output and Climate Change Technical Report which will be provided to the Environment Agency and available on request. This appendix describes how both the Grid SWZ and the East SWZ meet the definition of a resource zone.

The Grid SWZ is a large conjunctive use zone and, although not all resources within the zone can be shared, some of the major resources can be moved and used to support supplies in different areas. Due to the interconnected grid, the risk of supply failure is the same throughout the zone. Supplies can be moved around effectively to manage resource shortfalls.

A water resources computer simulation model, Water Resources Allocation Plan simulation (WRAPsim), is used to model our water supply network. The model is used to evaluate river flows, water storage and levels of service. WRAPsim schematics for the two resource zones are shown in Appendix B of the Deployable Output and Climate Change Technical Report. The schematics show major pipelines, treatment works, sources and demand zones. Our system is too complex to show the capacities and system constraints on these schematics, although these are all included in the WRAPsim model.

The schematics, associated system constraints, and resource zone integrity pro formas were shared and discussed with the Environment Agency in 2017, and the integrity of the resource zones was agreed.

2.4 Supply availability

We have produced a forecast of supplies over the next 40 years. This takes into consideration the factors which either increase or decrease our deployable output. We model supply availability using our water resource simulation model. This model takes account of constraints in our supply system and historic inflows and calculates how much water can be supplied, while maintaining a level of service of no more than a 4% risk of a temporary use ban in each year (one temporary use ban per 25 years on average) in both resource zones.

We also take account of temporary reductions to resource and treatment availability, for example to allow us to maintain our assets, in our planning. This is known as outage.

We allow for uncertainty within our supply and demand forecasts through a target headroom approach. Our supply forecast is described in detail in Section 3.

2.5 Demand forecast

We have also produced a forecast of how demand will change over the next 40 years. This forecast takes into consideration factors which could result in both an increase and decrease in demand. The key factors forecast to influence future demand for water include changes to population, housing, economic prospects, household metering and leakage management. Our demand forecast is described in detail in Section 4.

2.6 Supply demand balance

We use our forecasts of future supply and demand to calculate a supply demand balance for each of our two water resource zones. This balance compares the forecast water available with the forecast demand for each year of the planning period. If this balance shows a deficit between the available supply and the demand for water, we need to identify solutions to close the gap.

2.7 Available options

We have considered a wide range of options that could be used to address a future deficit in our supply demand balance. These options include those that will reduce demand, such as:

- leakage reduction;
- mains replacement;
- pressure management; and
- water efficiency.

As part of our twin track approach, we have also considered options for new water resources, for example:

- reservoir dam height raising;
- new resources (e.g. new borehole or river abstraction);
- desalination; and
- water trading/bulk transfers from other water companies.

2.8 Option assessment

We have assessed each option to define how much benefit (deficit reduction) it could provide. We also assess how much each option would cost, considering its whole life costs across a range of areas including capital, operational, social, environmental and carbon. When selecting our preferred solution, we consider the options costs and benefits to determine the best value solution over the long term.

To establish which of our options would deliver the greatest benefit, we have assessed each option, against the following criteria:

- Will the option meet the supply demand deficit whilst maintaining the current level of service?
- Is the option cost-efficient?
- Is it supported by our customers?
- Does it align with the outcomes presented in our Business Plan?

- Does it minimise environmental impacts?

2.9 Problem characterisation

Before producing our draft WRMP19 we carried out a problem characterisation evaluation in line with the UKWIR *WRMP 2019 Methods – Decision Making Process guidance,* (Atkins, 2016). The problem characterisation is carried out for each water resource zone and is used to evaluate the strategic needs and the complexity of individual zones. The guidance provides a decision-making framework to help water companies select appropriate investment appraisal and optimisation methodologies based on the outputs of the problem characterisation.

As we completed our problem characterisation at the start of our WRMP process, we based it on our WRMP 2014 supply and demand components and any new information available at the time of assessment such as potential sustainability reductions.

Problem characterisation is Stage 3 of the decision-making framework. Following the methodology provided in UKWIR *WRMP 2019 methods – Risk Based Planning,* (Atkins, 2016), we fed the output from Stage 3 into our risk based planning methodology. We then used the outputs from the risk based planning method as inputs to Stage 5 of the decision-making framework, "identify and define data inputs to model".

In WRMP14, we forecast that the Grid SWZ baseline scenario would be in deficit from 2018/19 onwards. By contrast, the much smaller East SWZ showed a surplus for the full 25-year planning period. We determined a solution to the Grid SWZ deficit in WRMP14 using *The Economics of Balancing Supply and Demand (EBSD) Guidelines* (UKWIR, 2002). This provided us with a least cost solution to the deficit, which we assessed against environmental impacts and customer preferences to develop our final solution.

For this plan, in line with guidance, we have completed problem characterisation for both the Grid SWZ and the East SWZ. At the time of this evaluation we assumed that the Grid SWZ would be in deficit following revision of the supply demand balance components. This means that we would need to select an appropriate

modelling method to identify a solution to the revised deficit. We assumed this because that is what our WRMP14 showed.

In WRMP14, our forecast for the East SWZ surplus was large, showing 30% greater supply availability than forecast demand. When starting work on the draft WRMP19, we had no concerns that any of the supply and demand components would have changed significantly since WRMP14. We carried out a problem characterisation to understand the complexity of the zone and if there were any issues that were not apparent in the previous plan.

For both zones, we identified a risk that the Water Framework Directive (WFD) requirements for achieving sustainable catchments by 2027 had the potential to reduce our available licence capacity. We did not expect any licence reductions to impact on the East SWZ deployable output due to the large supply surplus in this zone. There was a risk that the Grid SWZ deployable output would be affected. However, when were at the stage of problem characterisation for this plan we had insufficient information to assess the scale of the risk at the stage of problem. We have worked closely with the Environment Agency to understand this risk as we have developed our new plan.

There are two parts to our problem characterisation assessment:

- Strategic needs ("how big is the problem?") - a high-level assessment of the scale of need for new water resources and/or demand management strategies; and
- Complexity factors ("how difficult is it to solve?") - an assessment of the complexity of issues that affect investment in a water resource zone or area.

Our assessment of strategic needs includes three headline questions that explore the size of any potential supply demand deficit, and the cost (in relative terms) of the supply and demand management options. The three strategic WRMP risk questions apply to three types of risk:

- S -supply-side risks;
- D - demand-side risks; and

- I - investment programme risks.

The assessment of the complexity factors provides an understanding of the nature of the risks and vulnerabilities within the draft WRMP19. It raises several questions on the supply-side, demand-side and investment programme complexity factors of the supply-demand balance.

The aim of this process is to identify whether these complexities, in combination with the level of strategic risk, indicate that methods beyond the previous EBSD methodology should be considered. These factors also provide an indication of which tools may be suitable.

Table 2.1 Problem characterisation assessment for Grid and East SWZ

		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)	East SWZ			
	Medium (7-11)				
	High (11+)		Grid SWZ		

Table 2.1 shows the results of our problem characterisation for both zones. The East SWZ scores very low complexity and there are no strategic need issues as there was no deficit to address. Since we completed the problem characterisation, we have confirmed with the Environment Agency that no sustainability reductions are needed in this zone.

In WRMP14 for the Grid SWZ, we forecast a deficit, primarily because climate change would reduce the amount of water available for us to supply to customers in this zone. For the draft WRMP19, we identified an additional risk that sustainability reductions may also reduce Grid SWZ supply. Our problem characterisation classified the overall Grid SWZ problem as small, because demand remained relatively stable and the solution presented at WRMP14 was not considered to be contentious. However, the Grid SWZ complexity factors placed us inside the amber classification. This was partly due to the complexities associated with potentially significant sustainability reductions.

The methodology that we selected to address the anticipated deficit for this plan was to use the EBSD methodology to determine the solution to several scenarios. This would include the baseline supply demand forecast scenario with known sustainability reductions included. We also based alternative scenarios on the unconfirmed sustainability reductions, which would lead to greater losses in demand. This allowed us to understand how these larger potential reductions might impact on our solution. At this stage, our original intention was to apply the Real Options Analysis methodology if the scenarios presented a number of different pathways that could lead to alternative solutions.

However, we have worked closely in consultation with the Environment Agency to understand the implications of WINEP (the Water Industry National Environment Programme). From this work, we now know that sustainability reductions will not cause a deficit in the baseline scenario in either of our zones. We still need to carry out further investigations during AMP7 to understand sustainability reductions on a number of groundwater and river abstraction licences. We have run some scenarios looking at impacts on supply. However, in agreement with the Environment Agency we have not identified any supply demand scenarios based on these potential licence reductions.

As we have no specific risk scenarios due to sustainability reductions to test against the future solution, we did not include a Real Options analysis in the draft WRMP19. This position is unchanged for the revised plan.

We have therefore chosen to use the EBSD optimisation methodology to determine a least cost solution, with non-linear solutions tested in our WRAPsim deployable output model. From this we have identified a best value solution, taking account of environmental impacts, customer preferences and regulatory guidelines.

Figure 2.3 Grid SWZ decision making process

Objectives	• Single metric – supply / demand deficit driven primarily by climate change impact on supply
Approach	• Aggregated supply and demand components • EBSD produces least cost solution • WRAPsim used to verify non-linear solutions through system simulation modelling • If specific scenarios emerge use Real Options Analysis approach to develop probability ‘tree diagram’
Selection	• Expert judgement – best value solution incorporating SEA, HRA, WFD, resilience, customer and regulatory preferences
Solution	• Schedule – preferred programme • Adaptive – scenario / sensitivity testing

2.10 Drought risk assessment

We have carried out a risk composition as detailed in the *Risk Based Planning Framework (*UKWIR, 2017). Our risk is defined according to scoring of complexity factors, i.e. how difficult the problem is to solve.

2.10.1 Grid SWZ drought risk assessment

We have selected Risk Composition 2, which acts as an extension to the baseline EBSD analysis carried out under Risk Composition 1 (i.e. it is effectively a sophisticated form of sensitivity analysis carried out to generate a best value plan for the WRMP). Risk Composition 2 allows us to use methods which are not too complex or time consuming but should increase our confidence in our supply demand balance, especially in those areas of high uncertainty or complexity. This should give us the confidence that our options will meet any deficit.

Benefits of demand restrictions are included within the supply side estimates of yield using the same control rules contained in the behavioural WRAPsim model that is used to provide our deployable output assessment.

We believe that the way in which we calculate our deployable output and levels of service is compatible with Risk Composition 2. Our inclusion of demand side drought options, and of (reliable) supply side options allows our conjunctive use deployable output to reflect that of the whole system, and complements the ground water methodologies, which already account for supply side losses in drought yield.

In addition, we clearly explain the benefits offered by both demand and supply side drought options included in our deployable output assessment and extend our analyses to include plausible droughts outside our historic record. We also calculate deployable output for different scenarios, and we explain the influence of supply side interventions in relation to the links with our Drought Plan.

For this plan, climate change remains the driver for significant future uncertainty and sensitivity analysis to still be appropriate. We have assessed headroom using *A re-evaluation of the Methodology for Assessing* Headroom (UKWIR, 2002). We have also included a more extreme climate change scenario in our sensitivity testing.

2.10.2 East SWZ drought risk assessment

The modelling complexity for the East SWZ is low, as determined by our problem characterisation assessment. The East SWZ is included in our WRAPsim water resources behavioural model used to model deployable output, and in most cases we will use the same methodologies for the East SWZ as we do for the Grid SWZ. However, we use less complex methods for climate change assessment for the East SWZ due to the lower vulnerability to climate change.

2.10.3 Drought resilience statement

We have planned our system so that it can withstand any drought that is as severe as those that we have seen since our historical record began in 1920, including an appropriate allowance for climate change. We also test our investment proposals against a plausible range of future droughts. This helps us to ensure that our

investment represents a good balance between cost, environment and resilience to severe droughts.

In addition, we plan for more severe droughts than we have experienced in our historical record. We define our deployable output relative to our levels of service, and this means that our quoted deployable output is less than it would be if it were defined by any one of our drought events. This is demonstrated in Table 10 of the water resources planning tables, which is described more fully in Section 3.7.

2.11 Planning scenarios

Our plan is based on the dry year annual average for demand, and on our deployable output calculated from our 95-year inflow record (1920-2014) for supply.

Our East SWZ is supplied by a run-of river source (where water is abstracted directly from the river and not via storage reservoirs or lagoons), and small springs with limited storage. In addition, the area sees an increase in its population during the summer, due to tourism, and therefore could be susceptible to peak summer demands. However, the deployable output in the East SWZ is considerably greater than both average and peak demand. Therefore, there is no risk to supply in a time of high demand.

Network flexibility in our Grid SWZ means it is not susceptible to supply demand issues at times of unusually high demand.

Therefore, we plan for a dry year annual average scenario only in each zone as a critical period scenario planning is not required.

Our deployable output is defined by our levels of service, which means that no single drought in our historic record is our design drought. It is worth noting, however, that our most extreme drought in most areas was the one which occurred in 1995/96.

Our plan uses a climate change scenario to forecast supplies for the duration of the planning period and beyond, but we have a resilience tested plan where we consider alternative scenarios.

2.12 Levels of Service

Our deployable output is defined by our levels of service of:

- temporary use bans no more frequently than 1 in 25 years on average (4% probability in any one year);
- drought orders no more frequently than 1 in 80 years on average (1.3% probability in any one year); and
- emergency restrictions no more than 1 in 500 years on average (0.2% probability in any one year).
- These levels of service apply throughout our planning period.

Our levels of service and deployable output are inextricably linked, and we fully discuss our levels of service in Section 3.5. We outline our deployable output for our chosen level of service. However, in Table 10 of our water resources planning tables, we also demonstrate the different estimates we obtain for deployable output for different design droughts, including an Environment Agency reference scenario with a return period of 1 in 200 years (0.5% probability in any one year).

The Environment Agency has asked us to demonstrate that we are resilient to a drought with a return period of 1 in 200 years without having need to implement emergency restrictions such as standpipes and rota cuts. Our 1995/96 drought has a return period higher than this (depending on the return period analysis used), and our modelling shows we would require only level 3 restrictions (ordinary drought orders) for an event such as this. This level of resilience is reflective of the investments that we have made since 1995/96 in creating and reinforcing our grid system.

Our analyses in Table 10 demonstrate that even for a 3-year drought with a return period of over 1 in 400 years, we would not need to resort to rota cuts, although we would plan to implement some of our long-term drought options.

The *Water Resources Long Term Planning Framework* (Water UK, 2016) confirms that we plan to a much higher level of resilience than most other water companies, as do our drought response surfaces, shown in Section 3.7.

We have also been asked to quantify deployable output and incremental costs of ensuring resilience (no standpipes or rota cuts) at the Environment Agency reference level of service. This are shown in Section 3.5.

3 Supply forecast

This section describes how we have calculated how much water we can supply now and in the future – our supply forecast. We explain what we have included in our forecast, and how we have considered the effects of climate change. We show the links between our levels of service and deployable output and explain how we have considered other factors that may affect how much water we can supply.

3.1 Water resources

The Yorkshire Water region is bound in the west and north by the hills of the Pennines and the North York Moors respectively. The southern and eastern parts of the region are low lying. Annual average rainfall in the region is highest in areas of the Pennines, whilst low lying areas average less than half the volume of rainfall each year, with little seasonal variation.

Urban areas in the west and south are principally supplied from reservoirs in the Pennines. The Pennines and the valleys of the rivers Don, Aire, Wharfe, Calder, Nidd and Colne are the largest upland sources of water in the region. We operate over 100 impounding reservoirs, of which two are major pumped storage reservoirs. The total storage capacity of all the supply reservoirs is 160,410 mega litres (Ml).

We have an agreement with Severn Trent Water to abstract up to 21,550Ml per year from the Derwent Valley reservoirs in Derbyshire. This water is used to supply part of South Yorkshire.

In the eastern and northern parts of the region, the major water sources are boreholes and river abstractions, chiefly from the rivers of the North York Moors and the Yorkshire Wolds.

Most of these water resources are now connected by a grid network. This enables highly effective conjunctive use of different water resources, which mitigates risk

and allows optimal planning, optimal source operation, and resilient sources of supply both in drought and during floods.

Approximately 45% of the water that we supply is from impounding reservoirs, 30% from rivers and 25% from boreholes. This varies from year to year depending on weather conditions. In the dry year annual average planning scenario rivers are used more, with about 40% of supply coming from reservoirs, 40% from rivers, and 20% from groundwater.

As described previously, our region is divided into two water resource zones for planning purposes. Each zone represents a group of customers who receive the same level of service from either groundwater or surface water sources.

The Grid SWZ represents a highly integrated surface and groundwater zone that is dominated by the operation of lowland rivers and Pennine reservoirs. The eastern area of this zone is supplied mainly from borehole sources located in the Yorkshire Wolds and along the east coast (this was previously the East groundwater zone). This area is linked to the grid by the east coast pipeline completed in 2012.

In some parts of our region, there is the potential opportunity for changes to reservoir management to be made to help manage flood risk. This is illustrated by the trial that we carried out at Hebden Bridge over winter 2017/18. We will continue to explore this issue, recognising that possible flood risk benefits must be balanced against other risks such as water resources resilience and reservoir safety. We will continue to report on our partnership work on this issue through the Calderdale Flood Partnership Board.

The East SWZ is supplied by a river abstraction and moorland springs in the Whitby area.

3.2 Resources and abstraction licences

We have 100 public water supply abstraction licences for 156 sources. These have been reviewed as part of the Environment Agency's Catchment Abstraction Management Strategies (CAMS), renamed Abstraction Licensing Strategies in 2013. Table 3.1 lists the CAMS areas in the Yorkshire Water region. All are in the

Yorkshire area of the Environment Agency except for the Idle and Torne CAMS area which is in the East Midlands region. The objectives of the CAMS process are:

- to inform the public on water resources and licensing practice;
- to provide a consistent approach to local water resources management;
- to help balance the needs of water users and the environment; and
- to involve the public in managing the water resources in their area.

No changes to our abstraction licences were proposed by the Environment Agency as a part of the first two cycles of CAMS reviews, the dates of which are given in Table 3.1 below.

Table 3.1 CAMS review dates

CAMS Name	First Published (CAMS)	Last published (Abstraction Licensing Strategy)
Swale, Ure, Nidd, Upper Ouse	October 2003	February 2013
Don and Rother	October 2003	February 2013
Wharfe and Lower Ouse	March 2005	February 2013
Aire and Calder	May 2007	February 2013
Hull and East Riding	March 2006	February 2013
Derwent	March 2006	February 2013
Idle and Torne	March 2007	February 2013
Esk and Coast	August 2007	February 2013

We hold 13 Time Limited Licences (TLLs). All existing TLLs have been renewed by the Environment Agency, at current abstraction conditions, until their appropriate CAMS cycle end dates. The 11 licences that are now due for renewal in 2029 and 2030 were most recently renewed in 2017 and 2018. Table 3.2 below outlines the

Yorkshire Water licence time limits. We presumed all TLLs would be renewed on expiry and included no uncertainty related to renewal in this plan, as the renewal of all licences has been recently approved by the Environment Agency.

The licence for Carlesmoor Tunnel has expired, as following consultation with the Environment Agency it was agreed that a licence was not required for this source: an uncontrolled ingress into a tunnel, so we did not renew it.

We will be applying to increase a number of licences in our Grid SWZ in order to increase our resilience. These licence increases are not required due to a supply demand deficit in the resource zone, but in order for us to maximise our resources and networks in a sustainable way. The licences we will be applying to increase include reservoirs in West and South Yorkshire and two boreholes in North Yorkshire. This list may be reviewed as we assess our resilience and network options.

Table 3.2 Time limited licences

TLL Expiry Year	AMP period	No. of Licences
2027	AMP8	2
2029	AMP8	8
2030	AMP8	3

The only sources which have closed since WRMP14 were already excluded from our WRMP14 deployable output.

The future of some sources is currently under review. These include a North Yorkshire reservoir, (yield of approximately 0.6Ml/d), a West Yorkshire compensation reservoir, and two South Yorkshire reservoirs (yield 5Ml/d). Our WRMP19 model does not include the North Yorkshire reservoir, and has the South Yorkshire reservoirs reduced to 20% of their maximum volume, reflecting the current capacities, and the volumes if these reservoirs were to be discontinued. Investigations into the potential solutions continued during production of the

WRMP19, and we expect these reservoirs to return to full use at some time during AMP 7. We shall provide updates in annual reviews of our WRMP.

Following our drought permit applications in 2018, we will apply to increase the annual abstraction limit on the River Wharfe to increase our resilience.

3.3 Baseline operations

The process of planning and managing baseline water resources in Yorkshire is part of a fully integrated approach to operational planning from source to tap across the whole region. Our main objective is to ensure that good quality water is supplied at minimum cost to customers and the environment.

We have a weekly management process to determine key flow target settings (reservoirs, rivers, boreholes, water treatment works and pipelines) for the week ahead. The process uses the WRAP (Water Resource Allocation Plan) computer model, to determine the best use of available resources to meet demand and maintain security of supplies. Resources are selected to minimise costs, environmental impacts and carbon emissions.

The WRAP model takes account of expected demands, reservoir and groundwater operating rules, control curves and licensing constraints. Temporary constraints such as outages for maintenance work or water quality problems are also taken into account. The management of river resources is subject to licence conditions which restrict abstractions at times of low flow and permit increased abstractions during higher flows, typically in the autumn and winter.

3.4 Deployable output assessment

To determine deployable output, we have followed the methodology defined in the *Water resources planning tools* (UKWIR, 2012); Annex E of *Water resource and supply: agenda for action* (Department of the Environment,1996), *Re-assessment of water company yields* (Environment Agency,1997) and *A Unified Methodology for the Determination of Deployable Output from Water Sources* (UKWIR/Environment Agency 2000). Other deployable output assessment methods used include *Handbook of source yield methodologies* (UKWIR, 2014).

The *Water resources planning tools* (UKWIR, 2012), report describes a risk based approach for assessing deployable output, so that the degree of complexity required depends on the nature of the source or group of sources being assessed. The revised methodology realigns existing tools for calculating deployable output within a risk based framework. Many of the previous reports and methods used for assessment of deployable output are discussed below, and are still relevant, representing the existing tools used by the *Water resources planning tools* (UKWIR, 2012) methodology. The methodology takes into account the vulnerability to climate change.

The Grid SWZ is a large and complex conjunctive use resource zone, so the assessment method used must be one suited to this highly complex zone.

This WRMP19 provides a summary of our deployable output assessment. Further detail is given in the Deployable Output and Climate Change Technical Report, which has been provided to the Environment Agency and is available on request.

3.4.1 Ground Water deployable output assessment

We maintain an ongoing programme of work to performance test our operational boreholes and we have reassessed the deployable output of our groundwater sources, using a source reliable output (SRO) assessment, for the updated revised draft WRMP19. The average output that a groundwater source can be relied upon to produce in a drought year is termed the average demand drought condition deployable output.

3.4.2 Regional deployable output modelling

We model our deployable output using our WRAPsim water resources simulation model. Our deployable output is the highest demand we can meet whilst still meeting our levels of service, and we use the explicit levels of service method described in the *Handbook of source yield methodologies* (UKWIR, 2014).

We have updated our WRAPsim model for the following components: extension of inflow records, review of the demand profiles, update to hydraulic and treatment capacities, update of groundwater source reliable output studies, update of power

and chemical costs, and abandoned sources. We have reviewed water treatment work maxima to reflect changes in reliable throughput due to a number of factors such as water quality. Our technical report outlines maximum water treatment works capacities used in the WRMP14 and WRMP19 WRAPsim models and indicates the reason for any changes. This is discussed in more detail in Section 3.15.2.

For the Grid SWZ, the WRAPsim water resources modelling software is used to carry out the analysis required for the determination of deployable output. The model incorporates the following, which are required for the determination of deployable output:

- the same demand profile should be used for every year of the simulation;
- the defined physical capacities of the existing system should be adopted for the simulation;
- each modelled system must incorporate emergency storage;
- inflows from 1920 to 2014 (ensuring a long simulation including critical droughts of 1920s, 1930s and mid 1990s);
- licence conditions are adhered to;
- demands are maximised to the point of failure as required for the determination of deployable output, by re-running the model at increasing demands until the levels of service are just met; and
- the deployable output for the 1 in 25 year temporary use ban level of service for the year 2017/18 is the demand of the Grid SWZ demand zone.

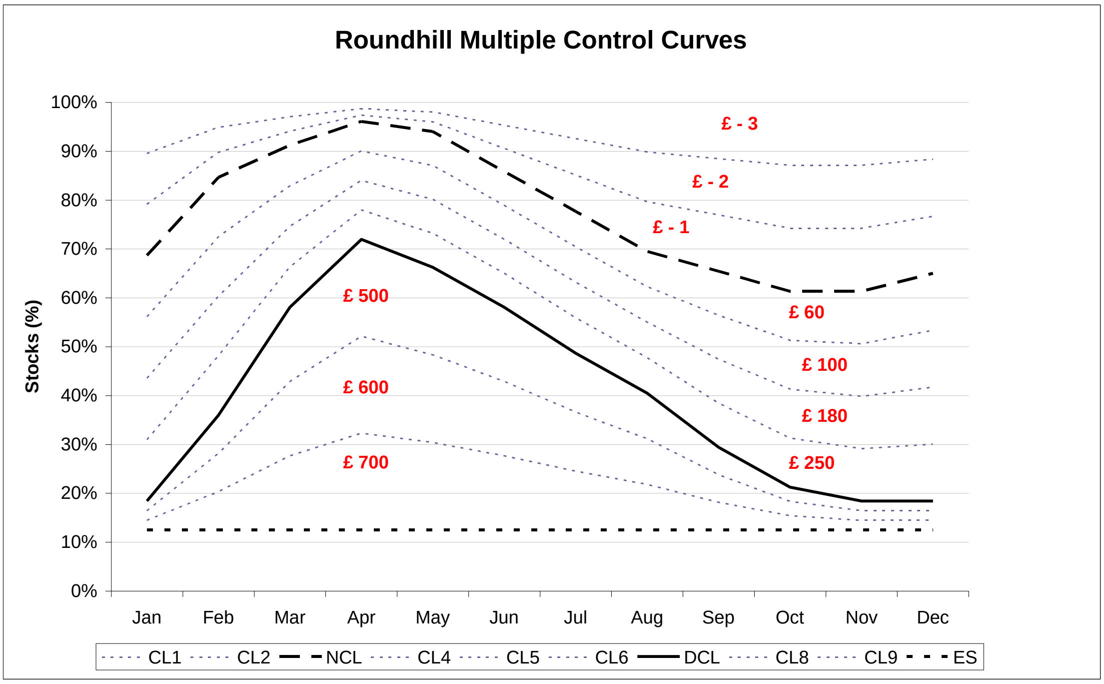
The supply reservoirs and the Hull borehole group in the WRAPsim model are modelled using control lines. The yield of the individual reservoirs and the control lines are calculated using minimum inflow sequences. This is to establish what reservoir stocks are required, given the historic minimum inflows, to maintain a given yield through the worst historic conditions.

Since we operate the sources within the Grid SWZ together, multiple control lines with notional costs, called penalty functions, are used to balance stocks between

reservoirs across the region. This ensures that reservoir stocks are balanced throughout the region and enables us to meet the requirement of achieving the same level of service throughout the resource zone.

Figure 3.1 illustrates how multiple control lines are used to assign different costs to water in different reservoir bands, thereby allowing stocks to be balanced between reservoirs.

Figure 3.1 Example of control lines and penalty functions



The reservoirs in the model are in five groups: Central, East (including the Hull borehole group, which is modelled as a reservoir), North West, South and South West Reservoir Groups. Each of the five reservoir groups must meet the agreed level of service: no more than 1 temporary use ban in 25 years (4% annual risk of occurrence); and no more than 1 drought order in 80 years (1.3% annual risk of occurrence). With the 95 years of inflow data used in the model, this allows up to three temporary use bans and one drought order for each of the five major reservoir groups.

Although the Grid SWZ does contain some sources with only limited connectivity to others, it is considered as a single resource zone. This is because most demand areas can be supplied by alternative sources and restrictions on use would be

applied to all demand areas within the zone at the same time. All areas within the Grid SWZ meet the level of service defined, i.e. no more than 1 temporary use ban in 25 years, on average.

The critical periods of drought are found to vary from one area to another, with the 1929, 1959 and 1995/6 events being dominant in Yorkshire. However, over the long-term each of the areas will fail a similar number of times for at least one of the restrictions.

When using the WRAPsim model to determine deployable output, we maximise demands to the point of failure. The model is re-run at increasing demands until the level of service is just met. This demand is the deployable output for the 1 in 25 years temporary use bans level of service (for the Grid SWZ). The demand of the Grid SWZ is the combined demand of all the WRAPsim demand zones within the Grid SWZ at the regional demand, when the level of service is just met (excluding the demand met by the Severn Trent import).

The sources in the East SWZ are constrained by the capacity of the River Esk water treatment works, and this is what determines deployable output in the East SWZ.

3.5 Level of Service

Our current level of service was formally adopted in April 2000 and delivered by 2001.

Table 3.3 shows our current level of service. This level of service is the basis for this WRMP, and our level of service is unchanged throughout the planning period.

Our levels of service throughout our planning period are also shown in Table 3.10.

We have estimated the return period of our level 4 restrictions (rota cuts/standpipes) as 1 in 500 years by analysis of minimum modelled reservoir stocks (*see UKWIR 2014, Handbook of Source Yield Methodologies, 11.3.2.4 Good practice examples*).

Table 3.3 Level of service

Restriction	Frequency of Restriction	Annual risk of restrictions (%)	Risk of restrictions in 25-year planning period (%)
Rotacuts/Standpipes	1 year in 500	0.2	5
Drought Order Implementation*	1 year in 80	1.25	27
Temporary Use Ban Implementation*	1 year in 25	4	64

* for a period of at least 3 months

As part of our customer research into our proposed outcomes and performance commitments for PR19 we discussed Drought Risk and the company position against the percentage of population that would be impacted by a 1 in 200 year drought risk measure.

When compared to other performance commitment measures, it came in the bottom five of importance, as customers are happy with our performance in this area and the level of service we plan to.

For PR19 we have not consulted with customers on levels of service for other restrictions as in PR14 customers were supportive of our overall level of service - with customers unwilling to pay more for an enhanced level of service or prepared to accept a lower level of service for a reduced bill.

For WRMP19, the Environment Agency has also requested that all companies calculate deployable output for a reference level of service for an event with a return period of 1 in 200 years. Our analyses show that our two season 1995/96 drought has a return period of between 1 in 140 years and greater than 1 in 200 years. We have scaled the 1995/96 drought to represent our reference level of service. This is described in section 3.7. Our supplementary report on deployable output calculation shows these analyses and also the calculation of deployable output for a

synthetically generated 1 in 200 year drought. The deployable output for this drought scenario is shown in Section 3.7.1.

For each of the level of service deployable output calculations, the model was run at decreasing demands until the level of service was just met (using the Explicit Failures method as described in*, Handbook of Source Yield Methodologies* (UKWIR, 2014*)*. The deployable output represents the highest demand at which the level of service is met, and the underlying assumptions for all runs are the same.

Figure 3.2 and Table 3.4 show the relationship between level of service for temporary use bans and deployable output for the Grid SWZ, plotted as annual risk of temporary use bans.

The link between groundwater sources and level of service are less clear than those for surface water sources, due to the limited data available for many groundwater sources. Many of our groundwater sources are constrained by licence or infrastructure, so alternative levels of service will not impact the deployable output of the sources. This may change in the future, if climate change alters the limiting factor constraining the source yield from the infrastructure or licence constraint.

Figure 3.2 Relationship between deployable output and level of service for temporary use bans for the Grid SWZ

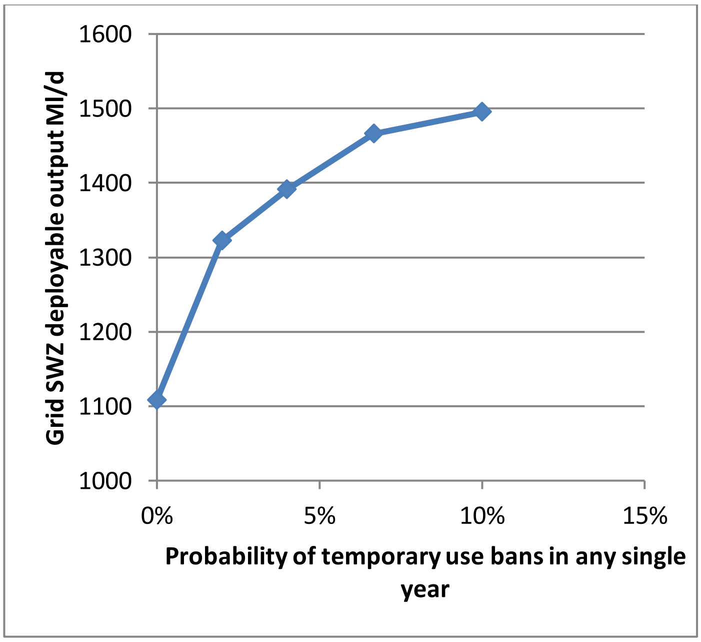


Table 3.4 Relationship between level of service for temporary use bans and deployable output for the Grid SWZ

Frequency of temporary use bans	Annual risk of restrictions (%)	Deployable output (Ml/d)
1 in 10 years	10	1496.53
1 in 15 years	7	1467.62
1 in 25 years	4	1392.61
1 in 50 years	2	1323.89
No restrictions	0	1110.02

The interconnected nature of the Grid SWZ means that even areas mainly supplied by groundwater sources have the same level of service as those supplied by surface water sources, as most areas can be supplied by at least one other part of the grid. There is therefore no need to assess individual source links between deployable output and level of service.

Our level of service is consistent with our draft Drought Plan 2018, and we expect to implement temporary use bans no more frequently than 1 year in 25.

The deployable output of the East SWZ is currently limited by the capacity of the water treatment works. The demand of the zone is far lower than this capacity, and consequently the zone experiences no restrictions. We do not intend to maintain the zone at the no restrictions levels of service, and if a deficit were to occur in the supply demand balance, we would reduce the levels of service to align with the Grid SWZ.

Following a review of the Yorkshire Water base model, the frequency of drought measures has been modelled for the 95-year period of record. Table 3.5 shows when temporary ban on water use and drought orders are triggered in each of our five reservoir areas. These reservoir areas are used for operational management of

our reservoirs. We balance stocks across areas during any one event as much as possible, to try to ensure that stocks fall through our control lines at the same rate.

Table 3.5 WRAPsim level of service report

Reservoir Group	Base model level of service			
	Frequency of temporary ban on water use trigger	**Years of restriction**	**Frequency of Drought Order trigger**	**Years of restriction**
Central	1 in 31 years	1929 1959 1995	-	
East	1 in 92 years	1992	-	
North West	1 in 31 years	1929 1959 1989	-	
South	1 in 31 years	1929 1934 1996	1 in 92 years	1996
South West	1 in 31 years	1959 1995 1996	1 in 92 years	1995-1996
Regional	1 in 46 years	**1929** **1959**		
Events with 3 TUBS triggered	1 in 31 years	**1929** **1959** **1995/96**		

Temporary bans on water use are triggered up to three times in each area, but they would only be implemented if triggered in three or more areas or regionally.

We last imposed restrictions in 1995 and 1996. This is consistent with forecast restrictions in our current model, although there are far fewer forecast restrictions than actually occurred in 1995 and 1996. This is due to the significant investment in the grid network, which has taken place since the 1995/96 drought, and to changes in operation and control lines which have resulted from analysis of inflows during extreme events. shows when temporary ban on water use and drought orders are triggered in each of our five reservoir areas. These reservoir areas are used for operational management of our reservoirs. We balance stocks across areas during any one event as much as possible, to try to ensure that stocks fall through our control lines at the same rate.

Table 3.5 shows that all reservoir groups except the East (consisting mainly of the Hull borehole group) trigger three temporary use bans during the 95-year modelling period. The East Group triggers only one temporary use ban (in 1992). The events that constrain the deployable output are shown in the table. This shows that different events are significant in different areas, with restrictions triggered in the different reservoir groups in different years. However, all areas meet our stated level of service and are therefore subject to the same risks of supply restrictions. In addition, temporary bans in water use are triggered in three areas in only three years: 1929, 1959 and 1995/1996, confirming our stated levels of service.

The duration of temporary use bans and drought orders are assumed to be at least three months, as once we have imposed a temporary use ban we are unlikely to lift such a ban until reservoir stocks have made a considerable recovery. Therefore, this minimum three-month duration is a sensible one to apply.

The incorporation of the borehole sources previously in the East GWZ into the Grid SWZ within the model for the WRMP19resulted in an improved level of service in the East Reservoir Group (Hull reservoirs and borehole group, which are the only borehole sources modelled as a reservoir within the WRAPsim model).

The East Reservoir Group has a higher modelled level of service than the surface water reservoir groups because it is different in nature (shown by the relatively flat

control lines), as it is predominantly an aquifer source. In modelled operation, the yield is limited below the normal control line, but, in reality, we would overdraw the source depending on conditions elsewhere in the system. The links of the grid to the areas supplied by the East Reservoir Group mean that these customers still experience the same levels of service as others within the Grid SWZ.

3.6 Reported deployable output

The deployable output for each resource zone is shown in Table 3.6. The Grid SWZ deployable output is calculated from the water resource simulation model. The deployable output of the East SWZ is the sum of the deployable outputs in the zone, which includes any locked in yield not utilised in the water resource simulation model, and is limited by the capacity of the River Esk Water Treatment Works.

Table 3.6 Deployable output

Water resource zone	Dry year annual average deployable output (Ml/d)
East SWZ	14.00
Grid SWZ	1392.61
Regional Total	1406.61

We have carried out sensitivity analysis of the impact of changes in demand to modelled deployable output. This showed that increasing the demand of the water resource simulation model run by just 2Ml/d resulted in failure of levels of service in four years (rather than the three allowed years) in the North West Reservoir Group.

The analysis described above details the methodology applied to determine the deployable output under the dry year annual average planning scenario. It should be noted that the deployable output demand is the highest demand that can be met whilst meeting our levels of service, and this is therefore, by definition, greater than the Dry Year Annual Average Demand.

3.6.1 What we have included in deployable output

We include some demand side drought interventions in our deployable output because our deployable output is defined by our levels of service. When a temporary use ban is implemented we assume a 5% reduction in demand, and when a drought order is imposed, we assume a 6% total demand reduction. In our draft WRMP19 we included supply side drought orders in the form of reductions in compensation flows, which cause a reduction in minimum reservoir stocks, but do not directly provide an increase in available deployable output. We have now removed these from our baseline deployable output assessment. Table 10 in the water resource planning tables shows the contribution of demand and supply side drought measures in our baseline deployable output and other drought scenarios.

3.6.2 Deployable output confidence label

These estimates of deployable output are based on records of 95 years of data. For some sources these data are all gauged, but for most there is a mixture of gauged and modelled data. A large amount of work has been carried out over the years to create the data series for sites where data were not previously available. Efforts have been made to obtain suitable data by extending the record and modelling to create the best possible available series. We therefore believe the confidence applied to the deployable output estimate according to *Water Resources Planning Tools* (UKWIR, 2012) is AB for both of our resource zones. Confidence grade A is assigned because the data is available and of consistent quality. Confidence grade B is assigned due to the record length (71-99 years of data).

For the East SWZ, we have simulated river flow data from 1920 to 2015 for this source, with river flows always greater than 20Ml/d. This is well above the deployable output for the zone, even without the inclusion of the spring sources. The development of the River Esk model for the East SWZ is described fully in the Deployable Output and Climate Change Technical Report.

3.7 Our resilience to droughts

We are one of just a few water companies that plan for droughts worse than those in our historic record. This is because our worst drought in 1995/96 was longer and

drier than any we had experienced, and we were not prepared for it. Since then we have improved our infrastructure links and our resilience to droughts.

We have carried out return period analyses on rainfall and inflow data and used these to inform the production of drought response surfaces. We originally produced a drought response surface for our draft Drought Plan 2017, analogous to the response surfaces produced in the report *Understanding the performance of water supply systems during mild to extreme droughts* (Environment Agency, 2015*).* For our updated revised draft WRMP19, we produced further response surfaces, and these are included in our final plan.

3.7.1 Return Period Analysis

In order to asses our resilience to droughts we have tested our system against a range of droughts.

We have calculated the return period of droughts of different durations based on analyses of our historic rainfall and inflows records. The results of the return period analyses give different return periods for individual historic drought events.

We have estimated the return period of events ending in August and November, as recommended for our system in the UKWIR, 2017, Drought Vulnerability Framework.

For each drought duration, from 6 months to 48 months in increments of 6 months, and for both November and August end months, we have;

- Calculated the minimum inflows sequences
- Constructed a flow frequency curve using the Gringorten formula
- Fitted a Generalised Pareto frequency distribution to the lowest 20% of flows (so that the distribution is fitted to low flows only and is a genuine extreme value distribution and not an attempt to fit the data to all years. (Malamud et al, 1996)

The distributions have been fitted to each drought duration in isolation, and the results are indicative of the droughts we have experienced. The 1995-96 drought was a particularly extreme event, with the 18 month totals for both inflows and rainfalls having a lower percentage of the long term average than the 12 month events. This particularly severe 18 month event reduces the estimates for all droughts of duration 18, 30 and 42 months.

We have also carried out analyses of monthly rainfall for some events, using both the methods described above and Tabony tables. The difference in results between analyses methods are discussed in further detail in our Technical Report on Deployable Output and Climate Change.

We have 95 years of record for inflows, and up to 135 years of rainfall data. Even with these relatively long records, the accuracy of return period analyses is poor when more than twice the record length, so the 500 and 1000 year return periods should be treated with extreme caution.

3.7.2 Drought Selection

We have selected a number of droughts to use to test the response and resilience of our system. Some are synthetic droughts, and for these we have also calculated the magnitude of droughts of specified durations and return periods. Others are historical droughts, and for these we have also calculated the return periods for given durations within the drought.

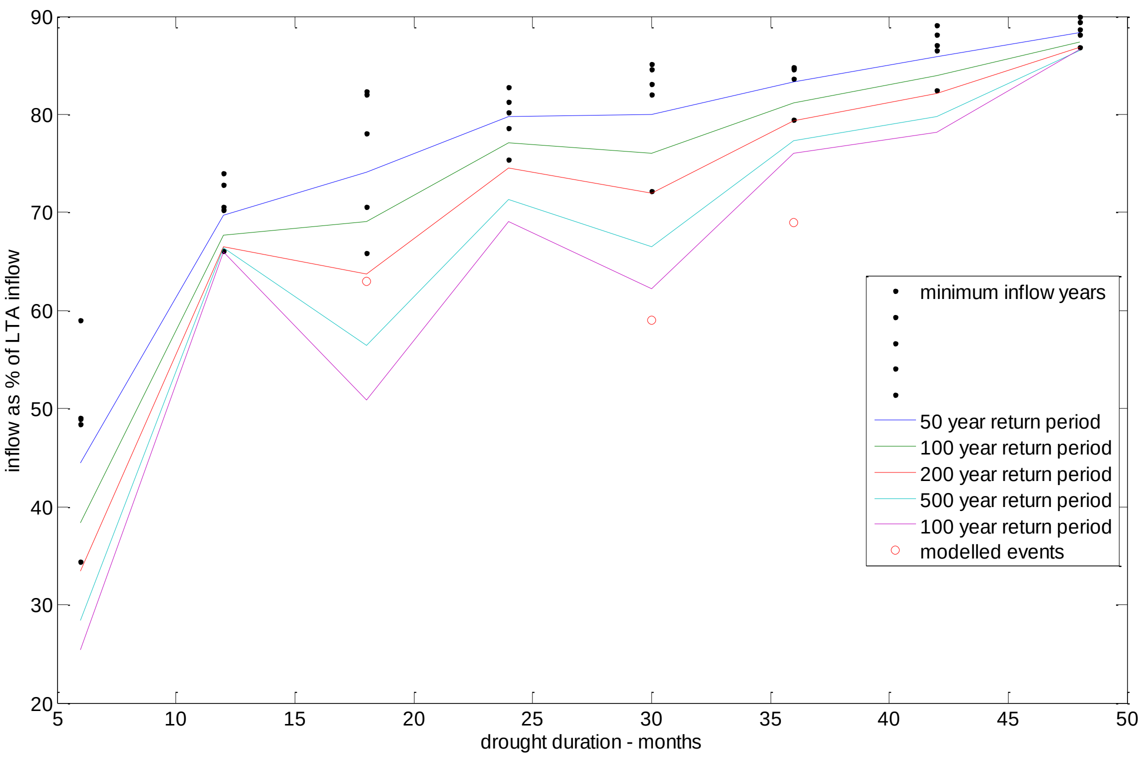
Figure 3.3 shows the five worst historic droughts for each drought duration for droughts ending in November. The calculated droughts for each duration for specified return periods are also shown, along with the droughts selected for modelling and inclusion in Table 10 of the Water Resources Planning tables, showing the links between the Drought Pan and the Water Resources Management Plan.

We have selected a reference drought with a return period of 1 in 200 years (0.5% probability in any one year) by scaling our worst historic drought in 1995-96. We have also selected the extreme 3 season drought we modelled in our drought plan to be used in Table 10.

The 30 and 36 duration droughts shown as red circles are the same extreme event, modelled in Table 10 of the Water Resources Planning tables. This event has a return period of greater than 1 in 1000 years when the return period analyses methods described in section 3.7.2 when droughts ending in November are modelled. The return period is between 200 and 500 years when rainfall return periods are modelled.

For the East SWZ we have scaled the 1976 drought based on our return period analyses to represent droughts of specified return periods.

Figure 3.3 Drought events and modelled return periods



3.7.3 Links between our WRMP and Drought Plan

Table 10 in the water resource planning tables shows the contribution of drought measures for a number of design droughts. First, we show our stated deployable output for our entire period of record, calculated according to our levels of service criteria, with up to three temporary use bans and one drought order triggered for

each of our five major reservoir groups. We have shown that the deployable output of our system is 1392.61Ml/d. This is a reduction from WRMP14 mainly due to sustainability reductions, and reductions in water treatment works capacity. Of this 1392.61Ml/d, temporary use bans and demand reduction drought orders contribute only 0.3Ml/d. When we include compensation reduction and supply side drought options, our deployable output is unchanged at 1392.61Ml/d, although modelled reservoir stocks are slightly higher.

When we model individual drought events, we can see that the relative contribution of demand reductions increases, as it shows the contribution over one or two years instead of 95 years. Our deployable output for our entire period of record is less than that for individual drought events within that record. We have defined the deployable output for individual events as the demand at which there are drought orders in three or more reservoir groups. Many companies define their deployable output in relation to a single drought event, and many companies use reservoir stocks hitting emergency storage as their failure metric. Because we define our deployable output according to our levels of service over our entire period of record, we are resilient to events more severe than any in our period of record.

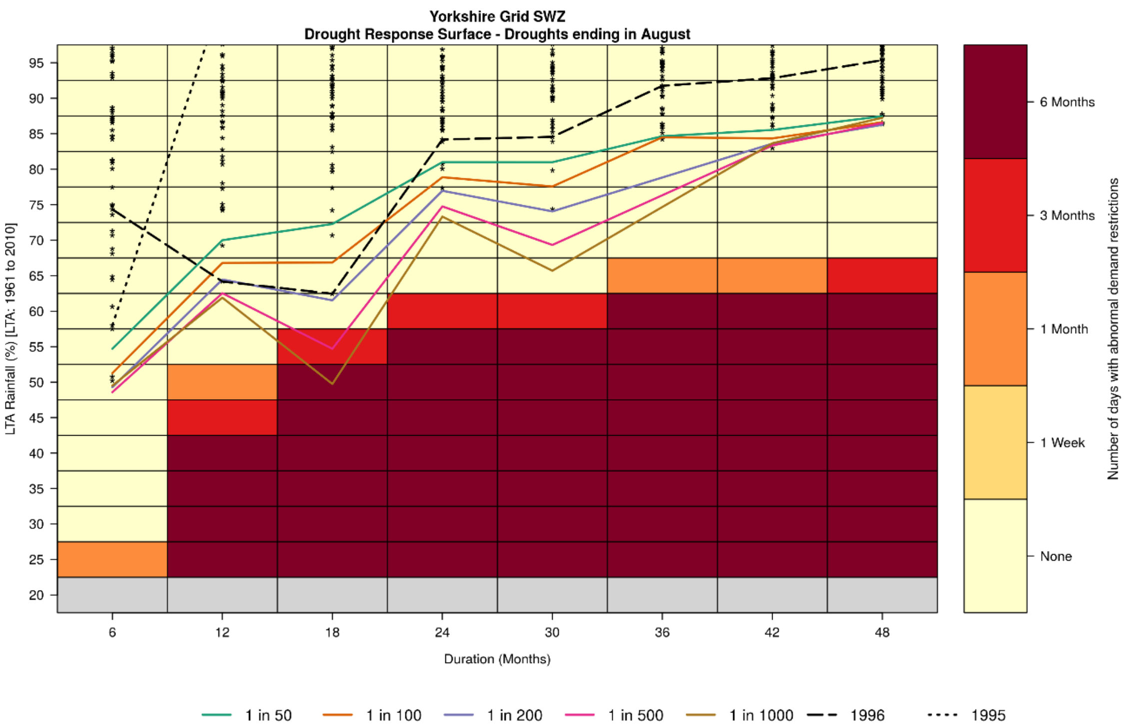
The deployable output for the scaled two season drought of 1995/96 (return period of approximately 1 in 200 years), is 1398.5Ml/d after the impact of demand reductions is taken into account (or 1416.2Ml/d unrestricted demand). This is more than when our levels of service are used to calculate deployable output over our entire period of record. We therefore would not require additional investment to be resilient to the reference 1 in 200 year drought event.

For our East SWZ, Table 10 in our water resource planning tables shows deployable output remaining at 14Ml/d for all drought scenarios up to the 500 year return period. The droughts modelled for these scenarios have been based on the analyses we carried out for climate change and are described in our Technical report on deployable output and climate change.

3.7.4 Drought vulnerability framework

The current UKWIR and Environment Agency project *The Drought Vulnerability Framework* was published after submission of our draft WRMP19 and recommends slightly different criteria for determining response surfaces to the original methodology we used. We have carried out analyses to demonstrate our drought resilience, and these are described in detail in our Deployable Output and Climate Change Technical Report, which shows a number of drought response surfaces. Drought response surfaces are shown for our Grid SWZ for droughts ending in August and November in Figure 3.4 and Figure 3.5. Our drought response surfaces show that we would not have level 4 restrictions for any event with a return period of less than 1 in 200 years.

Figure 3.4 Drought response surface for Grid SWZ (August end month)

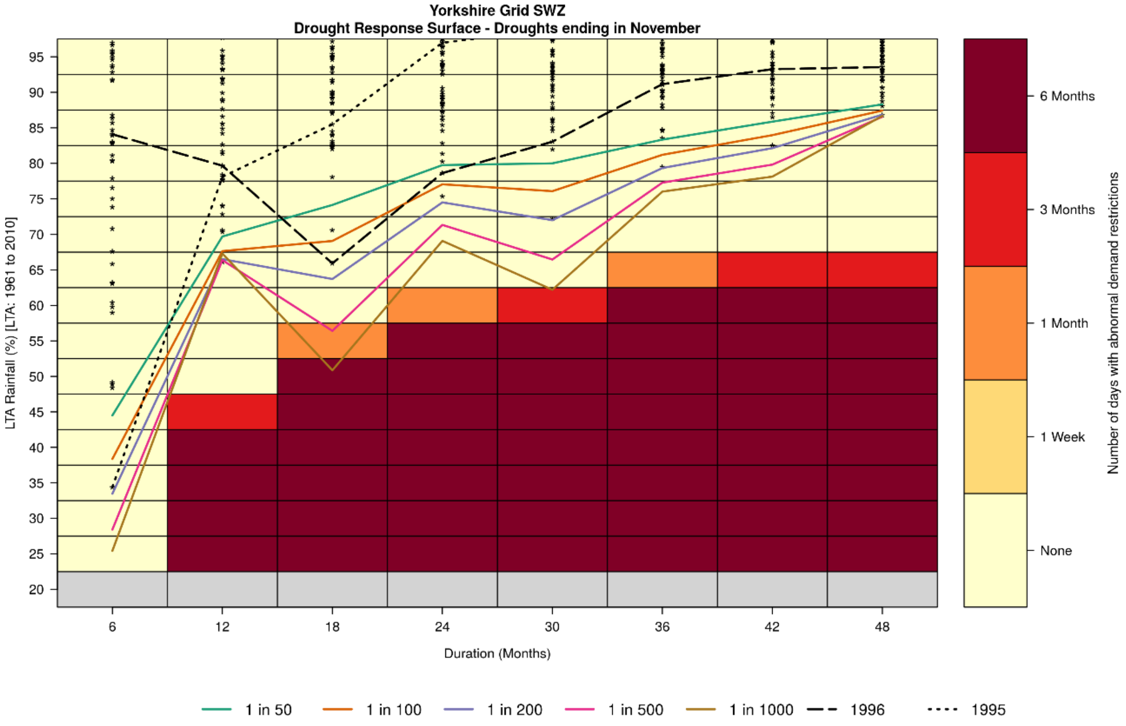


These surfaces have been calculated using:

- The simulation model run at our deployable output demand;
- using regional reservoir stocks below 20% as our failure metric; and
- based on percentage of long term average flows

Our drought response surfaces show that we would not have level 4 restrictions for any event with a return period of less than 1 in 200 years.

Figure 3.5 Drought response surface for Grid SWZ (November end month)



In addition, we have produced response surfaces to show the period of time when ordinary drought orders would be implemented, as we believe these provide a better understanding or our drought resilience (the *UKWIR 2017 Drought Vulnerability Framework* also used this metric in the case study of our system). These surfaces are shown in our Deployable Output and Climate Change Technical Report, and show that for droughts with a return period of 200 years or less there would be no restrictions for droughts ending in November, but for droughts ending in August, there would be up to 6 months of restrictions for droughts of 18 months. However, the surfaces do correspond well to our levels of service, with only the 1995/96 drought triggering drought orders in our historical record. The droughts modelled to produce these response surfaces are synthetic ones, based on an average inflow year, with flow ranging from 25% of average to 95% of average, for six month intervals. Real droughts are not so uniform, so these surfaces can only give an

indication of our system response to droughts. It should also be noted that there are uncertainties in the return period analyses, with the most extreme droughts in our record having return period of between 1 in 100 years and 1 in 1000 years depending on analysis method.

Both response surfaces show lower flows relative to the long term average for 18 month events than for the 24 month event. This is due to the extreme nature of the 1995-96 drought. Both of these also show restrictions for the 18 month events and not the 24 month events for both the 500 year and 1000 year return periods. This is partly due to the uncertainty related to estimating such high return periods from relatively short data sets, but also because the events ending in November are different. A 24 month drought ending in November started in December, whereas an 18 month drought ending in November started in June, so these events will have different characteristics, and it may be the case that a longer drought ending in a given month may have less severe restrictions than a shorter one.

Following the methodology of the DVF, we have not produced response surfaces for the East SWZ, as the screening indicated it was not required.

3.7.5 Drought resilience

Resilience is a key part of the Water Resources Management Plan and features prominently within our PR19 Business Plan. We believe our water resources modelling shows that we are resilient to drought. We plan to a drought more severe than any individual drought in our period of record because we base our deployable output on the levels of service of up to three temporary use bans and one drought order, and not on reservoir stocks reaching emergency storage. The most severe drought in our period of record is also a very extreme event, so we are confident that our system is resilient to a high return period event.

This is supported by the *Water Resources Long Term Planning Framework* (Water UK, 2016) report which states that we are one of only two water companies that plan to events more severe than those experienced. This is mainly because of the extreme experience of the 1995/96 drought which was unlike anything we had seen before, and the fact that our deployable output is limited by our levels of service with

respect to temporary use bans in three out of our five reservoir groups. It is therefore these less severe events which limit our deployable output.

We carried out a high-level screening assessment within the drought vulnerability framework, which indicates no requirement to produce drought response surfaces for our East SWZ.

3.8 Resilience

3.8.1 Resilience modelling

The Environment Agency Water Resource Planning Guideline and the *Guiding principles for water resources planning* (Defra, 2016) include testing the resilience of water supply systems to events other than drought, such as flooding and freeze thaw. This includes testing resilience not only to historic events but also to future events that could reasonably be foreseen. If appropriate, options to improve the resilience of our water supply network to these non-drought hazards should be included in our plan.

Resilience of our business and services has been a focus for a long time. Our customers consistently tell us this is a priority and the reliability of our essential services is critical to our communities, economic growth, environmental protection and human life.

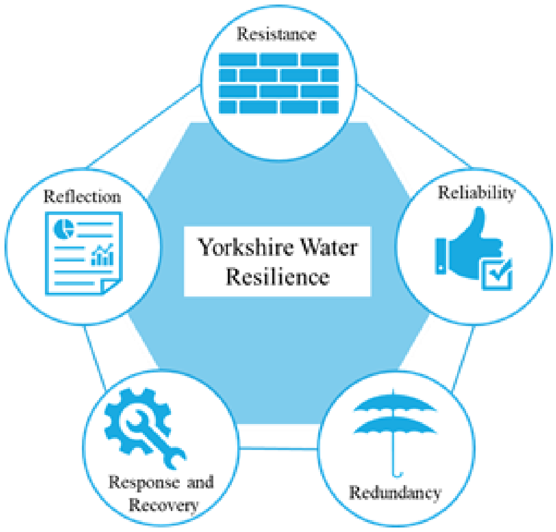
We have developed a resilience framework to assess the maturity of our resilience in all parts of the business, including operational, financial and corporate activities. This framework assesses resilience over past, current and future timescales to a comprehensive range of shocks and stresses that could interrupt our services, using the British Standard for Organisational Resilience (BS65000) and an extended version of the Cabinet Office model for effective infrastructure resilience. This framework allows us to quantify the resilience of all our activities through a comprehensive evidence-based assessment.

We monitor and plan for many factors including extreme weather, climate change, population growth, growing cyber threats, complex supply chains and global financial instability.

The five qualities of resilience included in our framework are shown in the diagram below.

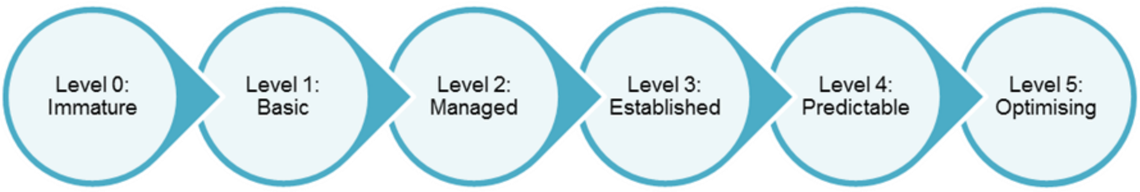
Figure 3.5 Five qualities of resilience

Resistance	Protection to withstand a hazard (e.g. a flood wall)
Reliability	The ability of an asset to operate in a range of conditions (e.g. asset design)
Redundancy	Designing capacity into a system (e.g. backup pumps)
Response and Recovery	Enabling fast and effective response to, and recovery from, an event (e.g. emergency planning)
Reflection	Continuously evolving as a result of learning from past experiences (e.g. raising actions in an incident review).



The level of resilience in 16 different systems (defined to cover all our operational, financial and corporate activities) has been assessed and quantified through a resilience model using the maturity scale in BS 65000, extended to include specific criteria across our five qualities of resilience. The six levels of maturity included in the assessment are shown below.

Figure 3.6 Levels of maturity



The assessment covered different timescales to provide a long-term view of resilience, to ensure our business plan and long-term strategy are effectively securing resilient water and wastewater services for customers now, and in the future. The four timescales assessed were:

1989	A high level review of our resilience at privatisation

Now to 2020	A detailed review of our current and near future resilience, assuming completion of our plan to 2020 including our investment to ensure upper quartile performance in areas that are most important to customers
2025	A detailed review of our resilience assuming delivery of our AMP7 plan
2050	A high level review of the long term, assuming continued levels of investment and projected trends for important factors like climate change and population growth.

The maturity assessment was led by an external consultant and involved comprehensive internal stakeholder engagement, including 40 workshops and interviews with colleagues from across the business.

3.8.2 Water supply resilience assessment

Our water service is assessed as one of the most resilient in the country, with advanced emergency and long-term planning and the flexibility provided by our grid network, which extends to 99% of the Yorkshire population. We have had no hosepipe/temporary use bans or other water restrictions since the drought experienced in 1995 and 1996, despite a number of subsequent periods of dry weather. More recently, we maintained supplies to customers throughout a period of exceptionally high demand in June and July 2018 as a result of our flexible grid network.

We have also maintained water supplies throughout severe floods and periods of extreme cold weather experienced in Yorkshire in recent years, with only a very small proportion of customers interrupted during the hard winter in 2017/18.

For example, there were 33 incidents where customer supplies were lost for less than 3 hours. In a small number of cases customers supplies were more severely impacted, with 6 customers losing supply for greater than 24 hours and 2 customer supplies interrupted for over 48 hours. Most of these longer duration incidents were due to access issues and all customers were provided with alternative water supplies until mains supply was resumed.

The resilience maturity assessment included four systems relevant to water supply resilience; land (catchment) management, water resources and collection, water treatment and drinking water safety and water distribution.

The assessment of these four systems in terms of historic and future resilience to forecast shocks and stresses is shown in Table 3.7.

Table 3.7 Historic and future resilience assessment of water supply systems

System	Priority shocks and stresses	1989	Now to 2020	2025	2050
Land (catchment) management	Climate change, environmental change, change in customer behaviour	Basic	Established	Established	Predictable
Water resources and collection	Climate change, population growth, environmental pressures	Basic	Established	Established	Optimising
Water treatment and drinking water safety	Aging infrastructure, vandalism, pollution	Basic	Established	Established	Predictable
Water distribution	Climate change, aging infrastructure, disruptive technology	Basic	Established	Established	Optimising

3.8.3 Water supply systems resilience

We recognise the need for a resilient water network so that we provide the level of service our customers expect and so that we can meet the demands of population growth and climate change.

The main indicator of network resilience is how often customers experience an interruption to their supply. Supply interruptions are generally caused by bursts, but can also be a result of planned maintenance, or damage caused by third parties such as road users or other utilities. In recent years, we have reduced the risk of a burst causing an interruption to supply by improving the resilience of our network, for example by improving our ability to re-route supplies from other sources.

Our approach to network resilience is based on the report *Resilience planning: Good practice guide* (UKWIR, 2013), and follows the three steps of risk screening, detailed resilience assessment and resilience implementation.

Our network strategy determines how we maintain the stability and reliability of our water distribution, managing risks such as burst frequency, leakage, poor pressure and water quality.

Our network policy focuses on significant interruptions to supply, and how we mitigate low probability, high severity events. The policy contains a framework that allows for consistent assessment of risk to our water network, particularly for risks that have a low probability of occurring but a severe impact on customer supplies if they do occur. Low probability, high impact water supply risks include:

- No safe, clean water available at a water supply system inlet;
- Unplanned outage at a key asset (trunk main, service reservoir, pumping station); and,
- Insufficient network capacity causing supply restrictions in period of very high demand.

For each water supply system, the consequence of a range of current and emerging hazards, including those identified in the guidance *Keeping the Country Running: Natural Hazards & Infrastructure* (Cabinet Office, 2011), was assessed. These include weather and climate related hazards, pollution, physical damage and issues with communications and power supply. The likely consequences of these hazards were considered to be; significant damage to or destruction of a key asset, lack of access to a key asset, lack of network capacity, supply chain disruption or failure of one or more key system (telemetry, network logging, work management etc.).

For each water supply system, maintenance and contingency plans have been developed to improve reliability, resistance and recovery of the network, to ensure supplies are restored within the shortest possible time.

3.8.4 Vulnerability to flooding

In December 2015 Yorkshire experienced severe flooding across the region. The scale, speed and timing of the floods over the Christmas period combined to test our service and asset resilience. The impact of flooding was greatest on our wastewater assets. However, there was significant impact on water supplies because of poor raw water due to 'scouring', combined with site power failures. Scouring lead to high levels of sediment and turbidity in raw water whilst power cuts resulted in significant interruptions to production at a number of water treatment works.

Despite this, the company incident management response to these events, combined with water treatment and network asset flexibility, resulted in no loss of drinking water supply to customers, and no significant impact on the quality of water supplied.

Following these events, we have carried out a review to establish lessons learnt so we can improve our future service and overall resilience to flood events. This has provided a better understanding of the requirements of critical asset resilience, including the use of risk assessments to define critical assets, development of appropriate response plans, and identification of the skilled staff and resources required to implement these plans.

3.8.5 Flood risk modelling - networks

Numerous bridges were damaged in the north of England during the flooding in 2015, with knock-on effects on not only transport infrastructure, but also utilities infrastructure, since bridges are often used to carry pipes and cables across watercourses. A number of key bridges were washed away in Yorkshire during the Boxing Day floods that year. Following this we commissioned research to identify assets at similar risk and prioritise mitigation strategies for those at greatest risk of failure.

Interactive PDF maps were generated to help visualise these risks across the Yorkshire Water asset network in three categories:

- Fluvial flood risk to the clean water asset network at river crossings;
- Fluvial flood risk to the waste water asset network at river crossings; and
- Surface Water flood risk to surface water assets such as pumping stations

The assets were categorised based on probability, consequence and overall risk of failure. Consequence of failure was based on data relating to the scale of impacts in terms of customers served (clean water) or pipe diameter (waste water) as a proxy for populations served. Probability of failure of road bridges was based on an analysis of bridges in Cumbria during the same period, for which failure data was available.

This allows spatial identification of assets with the highest risk of damage or collapse during a flood event. The information has been used to support identification of high risk river crossing assets for investment in PR19.

3.8.6 Flood risk modelling – non-network assets

As part of our climate change adaptation report we have assessed the risk to our assets from fluvial, coastal and reservoir flooding. This risk assessment has enabled us to prioritise investment at our most vulnerable and most critical sites. Where we have not been able to invest in capital measures, we have put in place operational contingency plans. Investment in a networked asset base and water supply grid provides flexibility to re-route supplies from alternative sources and avoid the impact of individual asset availability on customers.

We also have an Incident Management Framework for dealing with events beyond our normal operating conditions. This approach is in line with the guidance *Keeping the Country Running: Natural Hazards & Infrastructure* (Cabinet Office, 2011) which suggests activity is required across the four themes of Resistance, Reliability, Redundancy and Response and recovery to deliver effective resilience.

Following the significant flooding events in recent years we have carried out a multi-phase project to quantify the resilience of our above-ground assets to fluvial flooding. This involved an assessment of a range of evidence and information such as hydraulic river models, topographic surveys, LiDAR data and interviews with site operators. The impact of climate change on assets' level of resilience was assessed where data was available. Site specific reports for 150 most critical at-risk sites (water and wastewater assets) were produced, including predicted flood depths, current level of resilience and the height of critical equipment such as electrical control panels.

The project was used to inform the development of our fluvial flood risk guidance document. This sets out our aspiration to protect assets from a fluvial flood event with a 1 in 200-year (0.5% annual probability) return period. Five water treatment assets were identified as being at higher risk of fluvial flooding. Proposals to enhance flood resilience at these sites have been included in our 25-year investment planning optimisation.

We have also examined the risk of our above ground assets to pluvial (surface water) flooding.

3.8.7 Vulnerability to extreme weather

Climate change and extreme weather can impact our network in a number of ways; cold weather causes pipes to become brittle and burst, intensive rainfall causes landslips which can expose and damage pipes, high river flows cause scour and damage to bridge crossings, and dry weather causes the ground to shrink and move, affecting pipes and other structures.

Freeze-thaw is the most influential factor on leakage from cast iron pipes, which make up most of our distribution network. We have developed a water temperature predicative model which uses forecast air temperature and current water temperature to predict the point at which the water temperature will drop below the level at which we see an impact on the network – resulting in increased leakage and network failure. The predictive model provides seven days' notice and there are separate thresholds and monitors for river and reservoir sources.

This information is used to inform our winter planning and operational response to cold weather and subsequent freeze-thaw events. We take a stepped approach to winter planning that escalates as necessary to ensure an effective response to cold weather. Our 'Winter Plan' has three trigger levels – Winter Operations, Winter Escalation and Winter Emergency. The trigger levels for each of these are based on performance against our leakage target, air and water temperature, and the number of outstanding repair and maintenance jobs. Use of this information allows us to maintain resilient supplies to customers in the event of extreme cold weather.

Our winter planning and preparation was tested in Winter 2018, during the thaw following the cold weather in late February and early March. We experienced the highest March demand in 21 years, primarily due to leaks on customer pipes and within business properties. In advance of the severe weather forecast we significantly increased the deployment of leakage resources to prepare for the predicted increases in leakage and demand. We implemented an incident team resource plan, increasing roles within our control room and call centre, and staffing key water treatment works 24 hours a day to manage water production and ensure strategic storage levels were maintained.

Resilience of our network to freeze-thaw is robust due to a number of factors: our ability to model and manage supply and demand and balance reservoir levels across the region due to our grid network; telemetered logging of DMAs to quickly identify leaks, and our ability to rezone the network quickly to carry out repairs; and our winter planning which allows us to understand and plan for the potential impact of cold weather on demand and our network.

3.8.8 Enhancing water supply resilience

We recognise the need for a resilient water network to provide the level of service our customers expect and to meet the future demands of population growth and climate change. Current resilience of our water network has been assessed as 'Established' under our resilience maturity model, as described in section 3.8.1. To improve network resilience to an 'Optimising' level, we need to consider all aspects of resilience: resistance, reliability, redundancy, response, recovery and review.

Although renewal and refurbishment of assets such as water mains and pumping stations remains key to maintaining supplies to customers, optimal network resilience will be delivered through a combination of asset investment, operational best practice and use of new technologies to provide innovative and cost-effective solutions for proactive management of the water network.

For example, use of mains failure data and development of predictive models to optimise our interventions on the network, and continuing to develop our 'calm networks' operational best practice, with activities such as value operator training, pressure management and optimal mains replacement.

This combined approach of investment and operational best practice will minimise the number of incidents and events occurring on the water network and allow a quick and effective response when incidents do occur. This will allow the resilience of our water network to improve from 'established' to 'predictable' and ultimately 'optimising' over future planning periods.

3.8.9 Water catchment resilience

Sustainable land management practices are critical to the resilience of our water services. We are one of the largest landowners in Yorkshire, with 28,000 hectares of land across the region. We own about a third of the land from which we source water to supply customers. This ownership enables us to work closely with our farm tenants and other stakeholders to lead by example in our land management practices and actively support resilience. We also work with other landowners and stakeholders across Yorkshire to protect all our sources of water.

Working with many stakeholders over the last 15 years and more, we have matured conservation measures in response to water pollution from unsustainable land practices.

The quality of the raw water we collect in our reservoirs has been deteriorating in many catchments over recent decades, primarily a consequence of unsustainable land management practices. Whilst we enhance water treatment capabilities to ensure our customers always receive the highest quality drinking water, we also

have a range of programmes to address the issues at source to secure long-term resilience.

Our catchment management programme includes managing our 25,000 hectares of natural habitats to protect Yorkshire's raw water and biodiversity. In our region, many of the key catchments contain upland peat which must be in a good natural state to provide clean water to our reservoirs, rivers and water treatment works. In an area with high biodiversity and good land management practices, the diverse and complex community of plants, animals and micro-organisms work efficiently to filter and remove contaminants. Our programme also includes tackling a range of water quality issues, such as colour, pesticides, nitrates and saline intrusion.

The Sustainable Futures initiative is unique in the UK in terms of bringing together farmers, global food and drink producers, non-government organisations and supply chain partners - currently involving 190 farmers managing 150,000 acres of Yorkshire. Working with the consultants at Future Food Solutions, we have recently launched the next phase of this programme, called Sustainable Landscapes, with three trials across Yorkshire. A key focus is to collaboratively explore innovative ways to prevent farmland soil being lost to waterways. This helps our resilience by reducing the amount of pesticides, nutrients and soil entering our rivers and aquifers. It also helps the farmers involved make their businesses more sustainable and profitable.

Recently we have expanded our catchment programmes to help prevent flooding, planting 20,000 trees in the Calder Valley as the first of one million to be planted across the region over the next ten years. In addition to supporting our core water and drainage services, our approach to land management also improves resilience by supporting the economy, enabling recreation, protecting biodiversity and storing carbon.

We are expanding our existing land management programmes and introducing new ones to mitigate a legacy of unsustainable practices that are threatening the resilience of our services. Looking ahead, we recognise the need to further our efforts because this legacy is likely to be compounded by growing pressures to the natural environment from the changing climate, increasing pollution and population growth.

These are long-term interventions and it may take many years for the full impacts and benefits to be delivered. We continue monitoring the effects of our approach to inform our evolving land strategy. We are committed to protecting and enhancing the range of benefits that people take from our land, particularly for water quality, flood protection, nature conservation, recreation and carbon storage. We are using our six capitals approach to better quantify these benefits to inform improved decision making and investment choices.

We are committed to working in partnership and taking innovative approaches to sustainably manage our land, and to influence other land owners to do the same. We are also committed to sharing our research and monitoring data and working with policy makers to ensure effective legislation and incentive systems. The reform of the Common Agricultural Policy presents a great opportunity to ensure it is best supporting land owners to manage land sustainably for the long-term.

3.9 Biodiversity and ecosystems

All schemes featured in our WRMP19 were assessed against Strategic Environmental Assessment (SEA) criteria which included the objective 'to protect, conserve and enhance natural capital and the ecosystem services from natural capital that contribute to the economy' (for details of the SEA refer to Section 9.3).

Through consultation with regulators and key stakeholders such as regional Rivers and Wildlife Trusts, we have adopted three key principles to take forward within our future biodiversity programme:

- **Ecological resilience** – we want to see stronger, healthier ecosystems, more able to withstand the impacts of low frequency high magnitude events such as droughts or CSO spills. We recognise we have a diffuse impact on aquatic systems across the region and want to ensure that we can compensate for this in a sustainable manner.
- **An ambition of a net gain to biodiversity** – we want to ensure that our own negative impacts on regional biodiversity are minimised, mitigated, and where appropriate, compensated for, and that we

understand the natural value across our estate to enable us to manage it appropriately.

- **Innovation and partnership** – we recognise we cannot just do more of the same, and to fully catalyse benefits for regional biodiversity, we need to work differently, work with others and focus on how to deliver the outcome, not record an output.

The programme includes:

- A biodiversity enhancement programme, facilitating volunteering, and access to our sites for our customers and colleagues;
- Management of our Local Wildlife sites;
- Conservation of key aquatic and riparian species, where we have a unique ability to make a meaningful difference;
- A catchment-scale fish resilience programme, which will enhance the benefits of our standard investments, by working through Catchment Partnerships; and
- Outperforming SSSI Common Standards Monitoring condition targets and SAC and SPA conservation objectives on our land.

The delivery of these obligations is captured through our 'Land conserved and enhanced' performance commitment for PR19. We are also trialling an innovative commitment based on the additional environmental value we can generate from our resources, such as land holdings. Through our Beyond Nature programme, we intend to introduce new tenancies across our agricultural estate, with a stated outcome of delivering a wide range of ecosystem services and not just financial return.

The *Water industry strategic environmental requirements (WISER)* (Environment Agency, 2017) document gives a clear expectation that water companies will develop measures to contribute to biodiversity priorities, and through extensive consultation, we are confident our expected AMP7 programme of biodiversity focused measures will deliver this.

We realise that the most effective way to achieve an outcome will be to integrate biodiversity considerations across our schemes and plans, rather than deliver them as stand-alone schemes. As such, we have and will continue to revise our capital scheme framework requirements, repair and maintenance policies and land management practices to deliver this. Biodiversity is now a key consideration within our corporate investment Decision Making Framework and is becoming more central to our corporate approach to valuation and planning through its inclusion within our developing natural capital models.

We are presently working to ensure that the *Biodiversity Net Gain: Good practice principles for development* (CIEEM, CIRA, IEMA, 2016) are incorporated within our AMP7 capital works frameworks, particularly given the emphasis on biodiversity net gain within the revised *National Planning Policy Framework* (Ministry of Housing, Communities & Local Government, 2018) and the update to Defra's biodiversity offsetting metric due in Autumn 2018.

3.10 Sustainability reductions

We have worked with the Environment Agency to support Water Framework Directive (WFD) and River Basin Management Plans (RBMP) objectives in relation to ensuring our abstractions are sustainable.

Sustainability reductions are derived from the Environment Agency's Water Industry National Environment Programme (WINEP) programme. The principal driver behind the reductions is the WFD, specifically Heavily Modified Water Bodies (HMWB) and the requirement to prevent deterioration in the status of waterbodies. All our reservoirs are either designated as HMWB themselves or are located within a designated heavily modified river waterbody.

Under WFD, these types of waterbodies are required to meet Good Ecological Potential (GEP). One of the measures required to meet GEP is the introduction of a new, or modification of an existing compensation flow from a reservoir. This can impact on the yield of individual sources and can affect the deployable output of the whole system.

Environment Agency WFD investigations have identified which reservoirs and/or abstractions require flow measures and we have subsequently carried out an options appraisal on these sites, working closely with the Environment Agency and using national guidance.

Where abstractions are causing or at risk of causing WFD deterioration of waterbodies, there is no requirement for the mitigation to be cost beneficial, and mitigation measures must be put in place.

This process has identified which schemes are cost beneficial and which are not, and some schemes have been screened out on this basis. Our WRAPsim model rebalances available water resources and as a result the combined effect of a number of schemes can have a more onerous sustainability impact than a single scheme in isolation. A number of combined runs were performed in WRAPsim to give an overall sustainability reduction.

The most beneficial combination of schemes involves modifying a maintained flow, introducing compensation flows at three sites, modifying the existing compensation flow from one site and increasing the hands-off flow requirements at three sites. Overall, this results in a sustainability reduction of 1.5Ml/d which will take effect by 2024. It was not cost beneficial to introduce an appropriate baseline flow regime at two sites and as a result they have been taken forward for river re-engineering solutions.

The Environment Agency may identify additional reservoirs and/or abstractions requiring flow measures in subsequent phases of the WINEP. Our view is that any additional schemes should be progressed through the AMP7 Flow Adaptive Management scheme. This allows for modelling and investigation of any new changes, with the aim of permanent implementation (potentially resulting in a yield loss) in AMP8. The Environment Agency has agreed in principle with this approach.

We have agreed with the Environment Agency that we should carry out investigations during AMP7 for a number of abstractions which have been highlighted in the WINEP as having the potential to cause WFD damage or deterioration. These investigations will help us understand the impact of groundwater abstractions in areas of East and South Yorkshire, and the impact of

hands off flows for an abstraction on the River Ouse. Another Habitats Directive investigation will look at the requirements for and impacts of hands off flows for our abstractions on the River Derwent, working with the Environment Agency and Natural England (see section 3.14.2).

Any changes to abstractions as a result of these investigations may affect our deployable output in the future or may affect the yield of options to address a supply/demand deficit, but they do not affect our current deployable output for WRMP19.

An additional HMWB mitigation measure is the improvement of fish passage. We have worked with the Environment Agency to improve fish passage by constructing fish passes or removing barriers in the Don, Ure, Aire and Wharfe catchments. We continue to work with the Environment Agency on WINEP and are planning further fish passage schemes in AMP7 in the Don, Calder, Aire and Wharfe catchments.

By working with the Environment Agency to ensure that our abstractions remain sustainable, we are also contributing to wider environmental aspirations such as those outlined in the Government's Biodiversity 2020 policy, *Biodiversity 2020: A strategy for England's wildlife and ecosystem services* (Defra, 2011). Our ongoing work to enhance upland catchments, including our commitments to improve the condition of Sites of Special Scientific Interest (SSSIs), also contributes towards this objective. In addition, our emerging approach to the use of the six capitals – including natural – will help to further embed the principles of supporting ecosystem services within our future plans. This recognises also the value of the multiple benefits that catchment restoration can provide, including not only water quality, but also water retention, carbon capture and biodiversity.

3.11 Invasive non-native species (INNS)

We recognise that our abstraction operations present a pathway by which Invasive Non-Native Species (INNS) may spread. To help mitigate the risk of spread, we have been working closely with the Environment Agency, Defra and the Non-Native Species Secretariat and other water companies to implement our proportional actions from the GB Invasive Non-Native Species Strategy.

In summary, we have been working to understand the risk INNS pose to our operations through an extensive risk assessment and survey exercise across our reservoirs and water treatment works. We have been improving biosecurity through the funding of a biosecurity project officer in conjunction with other regional stakeholders such as Leeds University and the Environment Agency. We are also one of eight water companies supporting and funding the recent re-launch of Defra's 'Check, Clean, Dry' biosecurity campaign, aimed at reducing the risk of INNS reaching our reservoirs and rivers on anglers' and sailors' equipment).

We recognise through the Environment Agency's position statement on raw water transfers, that new schemes creating a new hydrological link will require mitigation to prevent spread of all life stages of any INNS. This is currently an infeasible task given the diversity of mitigation required to deal with microscopic organisms through to plant fragments and fish. This is recognised in the Environment Agency's PR19 guidance issued to water companies, and as such, we will be researching effective mitigation during the AMP7 period to enable us to meet this requirement in future.

The position statement notes that mitigation will be required on existing transfers on a gradual basis. Options to deliver this mitigation on a risk prioritised basis have been included within our PR19 submission for delivery in the AMP7 and AMP8 periods.

3.12 Abstraction reform

In accordance with the guidelines, we have not planned for any changes in deployable output as a result of abstraction reform. The expectation is that at the time of reform abstraction licences will be sustainable, or a plan will be in place to make them sustainable. The sustainability of our abstraction licences is addressed through our work with the Environment Agency on the WINEP, described in Section 3.10.

3.13 Climate change

3.13.1 Introduction

The *Water Resources Planning Guideline* (Environment Agency and Natural Resources Wales, 2017) states that a company's plan should consider the impact of climate change on baseline supply at resource zone level. The guidance includes several methods for incorporating climate change and hydrological uncertainty in supply forecasts. The guideline is largely based on *Climate change approaches in water resources planning - overview of new methods* (Environment Agency, 2013), and the more recent 2017 guidelines and supplements. In addition, we use evidence from reports produced for WRMP14.

The Deployable Output and Climate Change Technical Report fully describes the approach we have taken to climate change modelling. We have adopted the risk based approach recommended in the guidelines, by first assessing the vulnerability of our water resources zones to climate change, and then developing models according to the results of this risk based analysis. We have shared our proposed methodology and results with Ofwat and the Environment Agency.

This section of the WRMP19 gives an overview of the development stages that we have taken in investigating the indicators of climate change in the region to date. It shows how we have carried out basic and intermediate vulnerability analyses of our sources to climate change.

For the Grid SWZ we have calculated factors which represent the effects of climate change on river flows and reservoir inflows in Yorkshire catchments. We have done this using methods recommended in the *Water Resources Planning Guideline* (Environment Agency and Natural Resources Wales, 2017). These factors have been applied to the WRAPsim model inflow files, and we have run the model to calculate the deployable output of the system in 2085. We have interpolated deployable output in the years between 2017 and 2085. We have chosen not to use the trajectory recommended in the guidance, which linearly interpolates between 1975 and 2085, and would result in a loss of deployable output of 69Ml/d in the year 2018/19, which we do not believe is a likely scenario for Yorkshire. We have discussed this approach with the Environment Agency.

Any effects of climate change on deployable output will be considered relative to the deployable output of our base model in 2017/18.

For the East SWZ we have carried out tier 1 analysis as described in the *Water Resources Planning Guideline* (Environment Agency and Natural Resources Wales, 2017). and repeated the analyses carried out for WRMP14, using an update of the models derived for the River Esk.

3.13.2 Indicators of climate change

Before WRMP14, we commissioned Mott MacDonald to analyse updated trends for a number of sites and describes the application of seven different trend tests to rainfall, flow and temperature series. The results, which were reported in *YWS Climate Change Trends: Climatic Change Evidence and Trend Analysis for Yorkshire* (Mott MacDonald, 2012), indicated statistically significant trends in only two series (Derwent and Hebden Water). However, these trends showed differences in patterns. Analysis of Central England Temperatures (CET) data generally showed significant upward trends in average annual and seasonal temperatures.

Analyses were also carried out in other research projects commissioned by Yorkshire Water including; the Climate Change Risk Assessment (CCRA) and drought duration modelling (*Duration Modelling: Impact of multi-year drought events on resources and assets*, WRc, 2012). The CCRA formed part of a four-phase project to inform PR14 and longer term planning. Phase 1 was an impact and vulnerability assessment that provided both a look back at recent extreme weather events, and a comprehensive understanding of climate change projections for the Yorkshire and Humber region. The CCRA formed the second phase. The third phase was a detailed risk assessment, and these fed into the fourth phase, our detailed policy position on climate change.

Recent climatic events appear to fit with the climate change predictions indicated in the *United Kingdom Climate Projections 2009* (UKCP09) scenarios, although to date no specific individual event can be attributed to climate change. Despite trend analyses not being conclusive, it is prudent to base our WRMP19 on the best

available evidence for climate change over the next 25 years, which is currently the UKCP09 projections, although UKCP18 projections are expected next year.

We have not carried out further trend analyses since WRMP14, but the literature is unanimous that the impacts of climate change are increasing. In recent years, we have had extreme rainfall events causing flooding (Winter 2015/16), and research has been published indicating that climate change has made such events more likely (*CEH, 2016),* but it is not possible to attribute an individual event, or series of events to climate change.

3.13.3 Basic vulnerability assessment

The basic vulnerability assessment determines whether a resource zone is classed as high, medium or low vulnerability with respect to climate change, based on the WRMP14 climate change impacts. The Grid SWZ mid scenario had a loss of deployable output of 9%, and a range (difference between the wet and dry scenarios) of 18%, making it a high vulnerability zone.

Table 3.7 shows the thresholds used for defining high, medium and low vulnerability zones, and the East SWZ and Grid SWZ are plotted on it in their respective positions.

The East SWZ has a low vulnerability to climate change, so we have carried out tier 1 analysis as described in the *Water Resources Planning Guideline* (Environment Agency and Natural Resources Wales, 2017), using the future river flows factors for the River Ouse for the 2080s. However, because we developed rainfall runoff models for the River Esk for WRMP14, we have repeated these analyses for the 20 model IDs used in WRMP14, with 2030s UKCP09 climate change factors.

The Grid SWZ has a high vulnerability to climate change, so we have used tier 3 analysis with intermediate vulnerability analyses, and used UKCP09 flow factors for the 2080s, derived from rainfall runoff modelling of a number of catchments.

Table 3.7 Vulnerability scoring matrix showing Yorkshire Water zones

		Mid Scenario (% loss in deployable output)		
		< 5%	> 5%	> 10%
Uncertainty range (% change wet to dry)	<5%	East SWZ		
	6 to 10%			
	11 to 15%			
	>15%		Grid SWZ	

3.13.4 Intermediate vulnerability assessment and drought indicator development

For WRMP14 we carried out intermediate vulnerability assessment *UKCP09 Climate Change Scenarios in Water Resource Planning: Developing an approach for Yorkshire Water - Summary of Approach* (HR Wallingford, 2012) and selected 20 climate change models based on this assessment. We did this by using drought indicator analysis to select 20 representative model scenarios, 10 spanning the whole range and 10 in the drier vulnerable range established by the drought indicator analysis. All samples were weighted, with the 10 dry samples assigned a low probability to avoid a skew in resulting deployable output. However, we believe that our calculated deployable output for WRMP14 with climate change was skewed towards the drier range due to the large proportion of dry scenarios, and due to the fact that our record includes the exceptional drought of 1995/96. Scaling of this drought results in extremely low deployable output assessments.

For WRMP19 we have still carried out the initial and intermediate vulnerability assessments, but this time for the 2080s rather than the 2030s, as required in the

guidance. In addition, we have selected fewer scenarios in the drier range this plan. Instead, we have used stratification (*Sampling Techniques.* Cochran, 1977), to select 20 samples from the entire range of projections, with an additional three in the driest and hottest range. For the selection of 20 scenarios, we have selected more scenarios from areas of the stratified data where there were more model IDs, to ensure our samples are as representative as possible.

3.13.5 How we have used UKCP09 projections for water resources modelling

For the 23 model scenarios selected, we have used the Yorkshire and Humber administrative region rainfall factors and temperature changes (from which Potential Evapo-transpiration (PET) factors have been derived) and applied them to eight catchments for which rainfall runoff models were available. We have used fewer rainfall runoff models than we used for WRMP14, because for many cases the factors derived from different modelled catchments were very similar.

The UKCP09 model scenarios were applied to each of these rainfall runoff models, and flow series and factors were developed. These factors were then applied to the WRAPsim inflow files for 23 projections to establish the system deployable output for each of the 23 climate change model scenarios.

WRAPsim inflows, which are not modelled by rainfall runoff models, have been assigned factors from the closest similar modelled catchment.

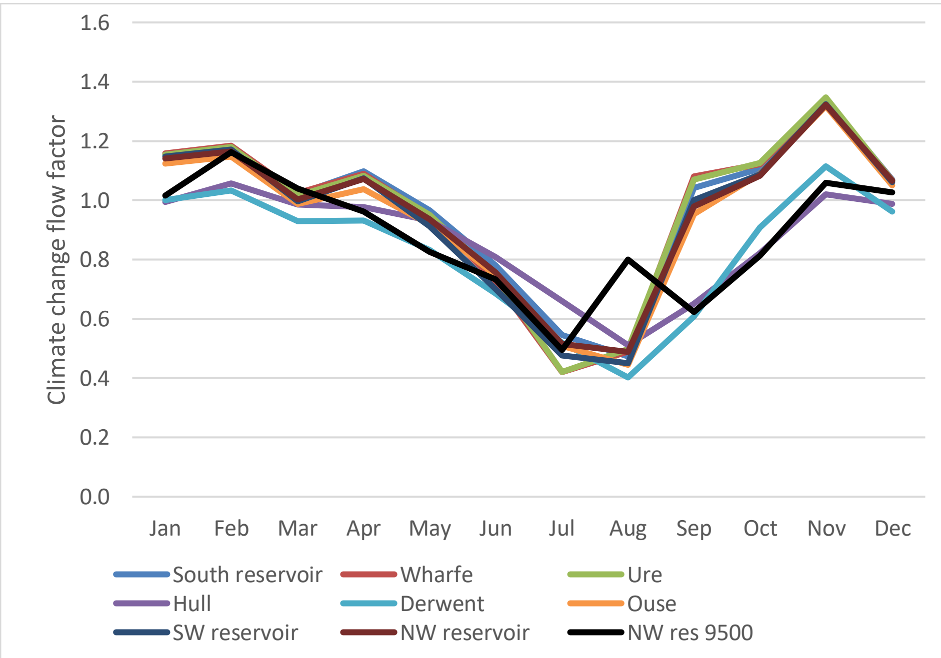
The use of the drought indicator analysis and the targeted sample approach has allowed us to use only 23 rather than a recommended 100 or more samples without the targeted sampling, which would not have been feasible. We have, however investigated the relationships between changes in temperature, rainfall and deployable output, and these analyses are described in the Deployable Output and Climate Change Technical Report.

We have selected one model ID for the water resources planning tables to use as our baseline scenario. This is model ID 7910. It is not the median scenario, but we have selected it as it is close to the median if the outliers are discounted, and it has a more sensible profile than the median (excluding outliers). For 2085, these low

scenarios generate deployable outputs of less than half the current deployable output. Analysis shows that the high PETs generated from the high temperatures produce extremely low flows in the rainfall runoff models. We believe these are unrealistic, as they are outside the range of model calibration, and we plan to investigate this further during the AMP7 period.

Error! Not a valid bookmark self-reference. shows the monthly flow factors for our chosen climate change (model scenario ID 7910). In this projection, for most catchments there is a minimum in August, and flows generally increase in the September to March period. The profile for one reservoir for the median climate change scenario model ID 9500 is also shown. We have used model ID7910 as our baseline scenario because the profile is less erratic than that of model ID 9500.

Figure 3.6 Flow factors for UKCP09 7910 2080s scenario



We strongly believe our drought in 1995/96 is such an extreme case that the application of factors to this results in a far lower deployable output than would be the case if this drought had not occurred. It is likely that the 1995/96 drought represents climate change that has already occurred, although we will not be able to establish this for many years to come. The application of climate change factors to this severe two year drought results in very low deployable output estimates. We

therefore believe it is appropriate to select a scenario which does not give us an excessive deployable output loss when applied to this extreme drought.

3.13.6 Interpolation of deployable output

The WRAPsim model is used to calculate deployable output for the baseline year and for the 2080s (the year 2085). We need to calculate the deployable output for all years of the planning period, and so to achieve this we interpolate between 2017 and 2085. The guidelines suggest using a linear trend from 1975 to 2085, but the guidance also acknowledges that this may not be suitable for all areas. We discussed our use of alternative scaling equations with our local Environment Agency and with our external auditor, and both agreed that a drop of 70Ml/d by 2020/21 was unlikely.

We have elected to calculate factors between 2017 and 2085, joining the 1975 to 2085 trajectory by the end of our planning period. This enables production of a smooth time series of deployable output, and avoids step changes in estimated deployable output, which might artificially influence the timing of investment decisions. The calculation of the trajectory is described in the Deployable Output and Climate Change Technical Report, which shows the different options we considered for the trajectory of climate change between 2017 and 2085 for one of the climate change model IDs. The recommended Environment Agency equation from the WRMP guidelines interpolates linearly between 1975 and 2085, and this results in a step change. We do not believe this trajectory is suitable, because it ignores the fact that the deployable output we have calculated is based on our climate up to 2017, and backdates the current deployable output to 1975, and then applies climate change to that value

For the East SWZ, we have interpolated using the equations from WRMP14, since was are using the forecasts for the 2030s.

3.13.7 Climate change model results

We calculated the deployable output for the climate change scenarios to determine the deployable output of the region in 2085. We used climate change perturbed

inflow files in the model and ran the model at varying demands until the levels of service were again just met.

We split regional deployable output between the two resource zones in the same way as for the current deployable output.

Finally, we estimated deployable output for each year between 2017/18 and 2044/45 using the methods described above.

Table 3.8 shows the calculated deployable output in 2085 and 2044 for each of the 23 UKCP09 model IDs (scenarios) for the Grid SWZ.

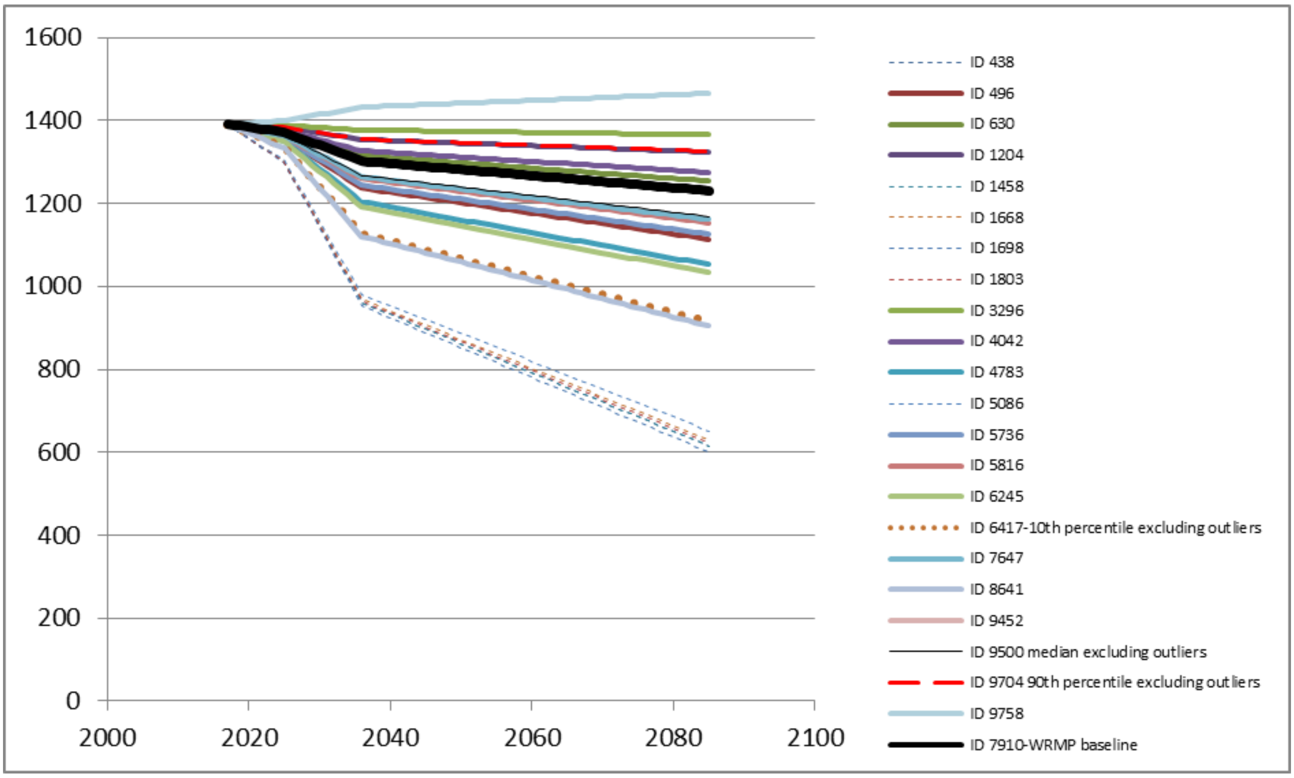
Table 3.8 Grid SWZ deployable output for 23 climate change projections in 2085 and 2044

Model ID	2085 Deployable Output (Ml/d)	2044 Deployable Output (Ml/d)	Probability %	Percentile %	Notes
1698	601.18	895.61	0	0	Outlier- additional dry
438	615.64	904.68	0	0	Outlier- additional dry
1458	615.64	904.68	0	0	Outlier- additional dry
1803	622.87	909.21	0	0	outlier
1668	630.10	913.75	0	0	outlier
5086	651.79	927.35	0	0	outlier
8641	904.41	1085.81	6	6	
6417	915.22	1092.60	5	11	10th percentile excluding outliers
6245	1032.70	1166.29	7	18	
4783	1052.92	1178.97	5	23	
496	1114.00	1217.29	5	29	

Model ID	2085 Deployable Output (Ml/d)	2044 Deployable Output (Ml/d)	Probability %	Percentile %	Notes
5736	1125.86	1224.73	7	36	
5816	1154.05	1242.41	5	41	
7647	1161.57	1247.13	9	50	
9500	1168.68	1251.59	5	56	Median scenario excluding outliers
7910	1230.65	1290.45	7	63	Baseline cc
9452	1233.01	1291.94	5	68	
630	1253.89	1305.04	5	72	
4042	1274.75	1318.12	7	79	
1204	1323.68	1348.81	6	85	
9704	1325.71	1350.08	5	91	90th percentile excluding outliers
3296	1365.32	1374.93	4	94	
9758	1465.27	1437.63	6	100	

Figure 3.7 shows the deployable output for the Grid SWZ, and how it changes over time due to climate change. The results shown and analyses described are for the current system configuration. Uncertainty is inherent with any modelling. A range of deployable output predictions are therefore given based on the 23 smart sampled scenarios.

Figure 3.7 Grid SWZ deployable output extrapolation



3.13.8 Climate Change in the East SWZ

Our East SWZ has a far lower vulnerability to climate change than our Grid SWZ. Due to the lower risk posed by climate change for this zone, we have carried out the tier 1 analyses recommended in the guidelines using Future Flows Hydrology change factors for the 2080s, (*Future flows and groundwater levels. Final technical report* (Prudhomme et al., 2012), and also repeated the analyses carried out for WRMP14 using 2030s change factors, but with updated models.

JBA Consulting developed a Probability Distributed Model (PDM) rainfall runoff model for the River Esk for our WRMP14 and have recalibrated it for this plan. We have modelled the River Esk flows under climate change using a simple spreadsheet tool which allows the input of a threshold and shows whether river flows are above or below this threshold. For the WRMP19we have also modelled this zone in our WRAPsim model.

There are no hands off flow requirements for the River Esk. However, if some of the more extreme climate change predictions do occur it is possible that maximising our

abstraction would result in a dry river. This situation would not be sustainable, so if this is forecast to occur, we would calculate a reduced deployable output for a given climate change scenario. We have modelled available abstractions for 2035 for each of the 20 UKCP09 model IDs used in WRMP14, assuming we always left at least 5Ml/d flow in the river.

The PDM modelled flow for the baseline has no flows less that 20Ml/d. This means that there are no flows less than 6Ml/d if the 14Ml/d deployable output of the zone were abstracted entirely from the river.

The PDM model is less responsive to higher summer temperatures than rainfall runoff models. Therefore, the flows produced may be higher than those that would be produced by a rainfall runoff model of the same catchment. However, the PDM modelled data gave a good fit to the observed data series at low flows.

If a climate change scenario causes the deployable output of the zone to be reduced, the new deployable output is recorded for that scenario. The 20 model scenarios are weighted according to the factors used in WRMP14, to calculate a median, 10th and 90th percentile deployable output for the zone.

The calculation of deployable output values and the use of the spreadsheet tool is described in full in the Deployable Output and Climate Change Technical Report which has been provided to the Environment Agency and is available on request.

Table 3.9 shows the calculated deployable outputs for the East SWZ. It shows that for most of the projections the deployable output is unchanged, confirming the low vulnerability of the zone.

Table 3.9 East SWZ deployable outputs for 20 UKCP09 climate change projections in 2035

Model ID	Cumulative weighting (%)	Deployable output (Ml/d)	Percentile
1068	1	11.8	
1628	2	13.0	

Model ID	Cumulative weighting (%)	Deployable output (Ml/d)	Percentile
1	3	13.5	
7518	13	13.5	10th percentile
4882	23	13.5	
1232	24	13.8	
9393	25	14.0	
5852	26	14.0	
9051	27	14.0	
7719	28	14.0	
1972	29	14.0	
2619	30	14.0	
3684	32	14.0	
3667	39	14.0	
5787	49	14.0	median
9784	59	14.0	
5669	69	14.0	
2734	79	14.0	
3160	89	14.0	90th percentile
7772	100	14.0	

When we calculated the deployable output for the East SWZ for the 2080s using the future flows factors, we obtained similar results, with most scenarios giving a deployable output of 14 Ml/d for the entire planning period.

3.13.9 Climate change conclusions

Table 3.10 shows the loss of deployable output due to climate change for the Grid SWZ at the start of each AMP (compared with the current year 2017/18) for the median climate change projection. The calculated deployable output is limited by our stated levels of service, and this table also shows our levels of service for each period (calculated for the base year and the 2080s and interpolated between these values).

For the East SWZ the median deployable output is 14Ml/d throughout the planning period.

A summary of deployable outputs for both resource zones, and how the deployable output changes over time, can be found in the Deployable Output and Climate Change and Technical Report.

Table 3.10 Levels of service and loss of deployable output for the Grid SWZ at the start of each AMP period, compared with the year (2017/18)

AMP	Year	Loss of deployable output compared with the year 2017/18 (Ml/d)	Annual risk (%)		
			Temporary Use Bans	Drought Order Implementation	Rota cuts /Standpipes
Base Year		0	4	1.25	0.2
Start of AMP7	2020/21	7.08	4	1.25	0.2
Start of AMP8	2025/26	18.88	4	1.25	0.2
Start of AMP9	2030/31	50.74	4	1.25	0.2
Start of AMP10	2035/36	82.61	4	1.25	0.2
Start of AMP11	2040/41	94.81	4	1.25	0.2
End of AMP11	2044/45	100.65	4	1.25	0.2

Previous analyses indicated that the factor with most influence on the calculated yield of our supply system is the inclusion of the 1995/96 drought in the data analysed. The yield was compared using flow factors, catchment factors and catchment modelled inflows. The different methods produced similar results for the same time periods, but only flow factors could be used for the entire period of record, dating back to the 1920s.

We consider that to best estimate our deployable output and level of service, the longest possible records should be used. This gives the most robust estimates of current deployable output and deployable output under climate change scenarios. Only flow factors can allow us to use our entire record length, as we do not have calibrated rainfall runoff models for all the catchments modelled in our WRAPsim model.

The Deployable Output and Climate Change Technical Report details how we have modelled the effects of climate change on groundwater sources, and the sensitivity analysis that has been carried out, to investigate the effects of different UKCP09 model IDs. The relative effect of climate change on groundwater and surface water sources is also discussed.

We are confident that the use of 23 smart samples offers the best and most feasible method of using the UKCP09 scenarios to model the effects of climate on deployable output. We are aware of the high degree of uncertainty associated with the climate change forecasts, and the nature and consequences of these forecasts.

During the AMP7 period we will continue our investigations into climate change trends, catchment models, and the use of the UKCP18 projections for water resources planning. To ensure that we understand what this new data is telling us, we are representing the UK Water Industry on the UKCP19 users' group, and we are leading work looking at how the UK water industry will use this latest evidence for future planning.

Implications of climate change on groundwater will be considered as part of ongoing work. We will continue to carry out groundwater modelling to assess the potential impact of climate change on yield.

We intend to use the UKWIR methodology developed in *the* 2017 UKWIR report *Climate Change and the WRMP*, and this will give us an idea whether the range of predicted future climates would result in deployable output reductions, and what changes in climate we would be resilient to, enabling us to focus analyses on those that were most likely.

We will also take into account any additional guidance that is published after the release of the UKCP18 scenarios.

We also intend to investigate the relationship between temperature change and Potential Evapo-transpiration, as we believe this has skewed the modelled flows in some of our modelled scenarios. Future climates predict temperatures outside calibration range of current rainfall runoff and Potential Evaporation models. This should give greater certainty in the range of likely modelled deployable outputs.

3.14 Scenarios to test our resilience

As part of our resilience tested plan, we have run a number of scenarios looking at the effect of various potential changes in supply on our deployable output. These scenarios are described below.

3.14.1 Failure of River Derwent weir

We have two abstractions from the River Derwent. The intake for one abstraction is upstream of a weir and sluice structure. These structures, which are owned by the Environment Agency and Yorkshire Wildlife Trust, are in a poor state of repair, and the Environment Agency has asked us to consider the risk of failure of these assets in our WRMP19. The consequence of catastrophic failure of these structures is that our ability to abstract at low river flows would be compromised. Our Asset Integrity engineers have inspected these structures, and do not believe that catastrophic failure is likely in the near future. Should failure occur, our ability to abstract at most flows would be unaffected, with an impact only occurring at low flows. We have carried out a risk review in relation to the failure of this weir, and should short term mitigation be required, we would install temporary pumps below the level of the intake structure to allow abstraction. A site mitigation plan has been developed to this effect. These assets are most likely to fail when river flows are high, as a result

of flood events and a build-up of debris behind the structures. The effects of failure, however, would only be felt when river flows were very low, so in the event of failure, we would have plenty of time to implement our mitigation plan before very low flows returned.

As a worst-case scenario, we have modelled the effect of not being able to abstract at this intake at low flows, and this results in a reduction of deployable output of 104Ml/d in the base year. This reduction is caused by a failure to meet demands in the driest years, rather than levels of service failures. Because we believe this asset failure to be unlikely, and because we have a mitigation plan in place to enable abstraction at low flows in the event of such a failure, we have not carried out a supply demand balance model of this scenario.

To ensure the most appropriate mitigation of this risk in the long-term, assuming that the condition of the weir and sluice assets deteriorate further, we plan to undertake an investigation in the AMP7 period that will review this intake in its entirety; the dependence on the weir and sluice structures is contained within the scope of the investigation.

3.14.2 River Derwent Common Standards Monitoring Guidance (CSMG) thresholds

Natural England and the Environment Agency have ongoing Habitats Directive investigations into the River Derwent. They have agreed to continue these investigations and committed to providing a hydrological target (either flow or level) by 2021. If they fail to agree a target, there will be no action. In the absence of such a target, we have modelled the standard CSMG targets for the two River Derwent abstractions. Imposing these targets (only 20% flow can be abstracted) results in a loss of deployable output of 130Ml/d in the base year. Again, this reduction is caused by a failure to meet demands in the driest years, rather than levels of service failures.

3.14.3 Severn Trent import uncertainty

We use a different water resources simulation model to Severn Trent Water. Because of this, and the fact that we each model our own systems, our modelled

averages of the Severn Trent Water import are different. We have a modelled value of 51.87Ml/d and Severn Trent Water model 48.46Ml/d. We account for climate change uncertainty of the Severn Trent Water import in our headroom, but we have also modelled scenarios where the import is reduced to below the value that Severn Trent Water model using their simulation model. This modelling shows our deployable output is unchanged if we use this import down to a level of 43Ml/d.

3.14.4 South Yorkshire reservoirs returning to full capacity

Two reservoirs in South Yorkshire are currently under investigation for reservoir safety schemes. Currently one of these reservoirs is being kept at only 20% of its capacity, and it has been included in our deployable output assessment at this capacity. It is possible that the preferred solutions enable a fuller use of these reservoirs. Scenario modelling has shown that returning these two reservoirs to full capacity (from 1,058Ml back to 2,779Ml) results in an increase in deployable output of 5Ml/d.

3.14.5 No supply side options in deployable output modelling

Our WRAPsim model assumes that supply side drought options are implemented when group reservoir stocks fall below the drought control line. We have modelled a scenario where this does not occur, and this is shown in Table 10 of our water resources planning tables. This demonstrates that although supply side drought options (reduction in compensation flows) are included in our model, our deployable output is not dependent on them, and they simply result in elevated reservoir stocks.

3.14.6 Climate change scenarios

Climate change represents one of our largest risks to deployable output and is also one of our largest areas of uncertainty. We have modelled deployable output for 23 climate change scenarios using our WRAPsim model and used only one of these (7910) for our baseline forecast in our supply/demand balance.

We have used model ID 9500 as an additional scenario because it is the median (excluding outliers) of the 23 scenarios and represents a worse case than our chosen scenario.

3.15 Water Transfers

3.15.1 Raw water transfers

In our WRAPsim model, the Severn Trent Water import has an average of 51.87Ml/d. We have consulted with Severn Trent Water, and their modelling gives an average export from their system of 48.46 Ml/d. Although there is a small difference in our modelled values, we have modelled scenarios where the average of the import from Severn Trent Water is only 48Ml/d. In our model, this does not change our deployable output. Severn Trent Water have also modelled a scenario with our assumed 51.87Ml/d export from their system. We are therefore confident that Severn Trent Water would be able to supply our import at a rate of 51.87Ml/d, and that if we could only import their modelled value of 48.46 Ml/d, our deployable output would not be compromised. Any uncertainty will be accounted for in our headroom component.

We have modelled the Severn Trent Water import for our climate change models. As with our other climate change modelling, we have used model ID 7910 for our water resource planning tables and used the others to calculate the headroom component for the Severn Trent Water import. This resulted in a year on year reduction in volume during the planning period.

Severn Trent Water has carried out its own climate change modelling which shows our import reducing to 47.95Ml/d by 2045.

The Severn Trent Water values differ to the Yorkshire Water value for a number of reasons:

- Yorkshire Water used factors for the Humber river basin/ Yorkshire region whereas Severn Trent Water used flow factors for the Severn river basin/ Midlands region;
- We both used a risk based approach, which identifies UKCP09 model IDs based on drought indicator analysis and the risk of low reservoir stocks. The risk based analysis allowed the selection of model ID's which best represent each companies' level of risk, but these model IDs are not the same; and

- Severn Trent Water have used 2030s climate change scenarios, and we have used 2080s.

In addition, we use a different water resource model to Severn Trent Water, we each have different levels of service and we each model our supply region but do not model other company's regions.

We have worked with Severn Trent Water to improve the way we model the transfer between our systems for WRMP19 but modelling differences in different models are inevitable. We both model our own system in detail and make assumptions about the use each other makes of the reservoirs. Our scenario modelling has shown our estimates are robust to this modelling uncertainty.

The Severn Trent Water import is transferred directly via a tunnel from an impounding reservoir to our water treatment works, where it is treated via appropriate treatment processes to required water quality standards. Due to the direct transfer of water to the treatment works there is no quality risk to a receiving waterbody.

This raw water import is the primary water supply to the treatment works and the treatment process has been designed to produce water to appropriate potable water standards.

The bulk transfer agreement for this import terminates in 2085, with an early ‘break clause’ which allows termination by either party from 2035 following a 5 year notice period. In their draft WRMP, Severn Trent Water included a 15Ml/d reduction in the import volume from 2030 in their best value plan. Severn Trent Water has subsequently confirmed that they no longer require a reduction in our import in 2030. We have committed to work together to investigate options for varying the agreement in the wider context of the Water Resources North Group. This joint work will involve water resources modelling of the Derwent Valley system and developing options for the Derwent Valley and wider Yorkshire Water and Severn Trent Water systems.

3.15.2 Treated water exports and imports

We have one minor treated water export from the Grid SWZ to Anglian Water Services. In line with previous years, we have assumed the export is 0.31Ml/d throughout the planning period.

3.16 Drinking water quality

The WRMP takes account of all statutory obligations for drinking water quality. Protection of raw and treated water quality is fundamental to water resources resilience and maintenance of our current and future deployable output.

In terms of the quality of drinking water supplies, we abide by Section 68(1) of the Water Industry Act 1991 and apply this governance to both our own sources and existing and potential transfers, in compliance within Regulation 15 of the Water Supply (Water Quality) Regulations 2016. We take a consistent approach to drinking water quality across both water resource zones.

In preparation of the WRMP19we have followed guidance on drinking water quality provided in the Water Resource Planning Guideline. No specific guidance was provided by the Drinking Water Inspectorate for the draft WRMP19 or the water quality submission for the 2019 Price Review.

As part of the assurance process we made a clear statement to the Chief Inspector of Drinking Water that our draft WRMP19 did not assume operating in ways which compromised drinking water quality to meet future demand for water. Where we experience or predict non-compliance with drinking water quality standards, due to the impact of raw water deterioration, we take action in a range of ways to mitigate this.

In general, where raw water deterioration drives the risk of failure in drinking water quality in the period during AMP7 to mid-AMP8 we will provide enhanced treatment processes, supported by catchment management activity to ensure the sustainability of the solution. Where Drinking Water Directive failure appears likely between mid AMP8 and AMP10 we will promote catchment management to secure raw water quality, supported by minor treatment enhancements. Where raw water deterioration

poses long-term risk to drinking water quality we will promote catchment management activity to prevent this impacting on drinking water quality.

In planning this activity, we have regard to the use of Drinking Water Protected Areas and Water Safeguard Zones as enablers for this activity. Catchment schemes are developed with the Environment Agency through WINEP methodologies and drinking water treatment improvement schemes are developed with the Drinking Water Inspectorate through their Undertakings and Notices processes. There are a range of uncertainties associated with water quality management through catchment schemes; some, such as product substitution for metaldehyde give clear cause and effect; whereas others, such as peatland restoration may deliver benefits over a much longer timescale.

For over 10 years we have undertaken remedial and protective activity within our catchments with the aim of reducing the risk of water quality deterioration, particularly mitigating an increasing trend in colour from upland catchments.

Our long-term strategic objective is to meet the standards required by the Drinking Water Directive, together with our national requirements, and we have plans and processes in place to achieve this goal over time.

We currently have one significant potential area of non-compliance with these standards, relating to the risk of seasonal failures of the standard for the pesticide metaldehyde. The other risk is production of disinfection by-products (DBP - trihalomethanes) caused by the increase in dissolved organic carbon (DOC) in many of our raw waters. The chlorination of DOC residuals after treatment results in the formation of DBPs, which we have an obligation to minimise (Regulation 26).

Our plan is to take a twin-track approach to protecting drinking water quality and deployable output. We are proposing more catchment activity through WINEP in the AMP7 period and beyond, with the goal of halting the decline in raw water quality and consequent risks to treated water quality. However, evidence gained over the past 10 years has shown that, in some catchments, land management will not provide a sufficiently rapid improvement in water quality. In these cases, catchment management will be complemented by water treatment solutions. This may involve

additional treatment stages, such as MIEX (magnetic ion exchange), or upgrading and expanding existing treatment assets.

Further detail of our approach to resilient catchment management is provided in section 3.8.9.

3.16.1 Source protection

Under the WFD, water sources are protected, and mechanisms are in place to identify Drinking Water Protected Areas for catchments where there is a risk of deterioration, mainly through human activity. Where action is required, Safeguard Zones, sub-catchment areas can then be defined in collaboration with the Environment Agency, allowing the causes of deterioration to be addressed by working with landowners and interested parties under a Safeguard Zone Action Plan (SgZ-AP).

The Environment Agency has defined Source Protection Zones for groundwater sources used for public drinking water supply. These zones show the risk of contamination from activities that may cause pollution of the groundwater. The Environment Agency uses these zones to set up pollution prevention measures in areas at higher risk, and to monitor the activities of potential polluters nearby.

3.16.2 Water quality risks

Our three primary risks to drinking water quality are colour from the peat uplands, pesticides from lowland rivers, and nitrate, especially in groundwater. These require a range of solutions to mitigate the risk to drinking water supply.

3.16.3 Colour

Increasing raw water colour is a risk in upland catchments due to deterioration of peatlands. The major cause of this degradation is how the vegetation on top of the peat has been historically managed. Overgrazing, artificial drainage (known as grips), atmospheric pollution and the burning of heather for grouse moor management all lower the water table and damage the structure of the underlying peat.

A long-term programme is ongoing to restore the hydrology of peatland catchments in Yorkshire. We work with stakeholders to re-vegetate bare peat and to identify mutually beneficial land management practices and policies which will deliver a sustainable ecosystem across Yorkshire's upland catchments. This will reduce the colour in raw water from these catchments, preventing water quality deterioration and loss of deployable output.

3.16.4 Pesticides

Our approach to pesticide reduction is the development of partnerships to promote best practice in pesticide use and alternative approaches to pest management, reducing the reliance on chemical control. In partnership with Natural England, we employ catchment officers to promote catchment sensitive farming in high risk sub catchments to protect both drinking water quality and deployable output.

3.16.5 Nitrate

Nitrate is a risk to our groundwater sources, as these are in the lowland areas of Yorkshire where arable farming predominates, and fertiliser use is widespread. In the past few years we have investigated the risk to our catchments from nitrate application. This will now allow us to work with farmers in high risk areas to better manage the catchment and reduce water quality and outage risks.

In addition to catchment management we consider treatment options, such as blending groundwater from different sources to ensure nitrate levels in supplies are kept within the required limits.

3.17 Outage

Outage is a planning allowance used to represent temporary reductions in water available for use (WAFU) due to planned or unplanned events. Headroom, described in Section 7, is also a planning allowance and is used to account for risks of permanent reductions in future supply.

Further reductions in supply occur during the process of abstracting and treating water before putting into supply. These are explained in Section 3.18.

We assess outage using the methodology: *Outage Allowances for Water Resource Planning* (UKWIR, 1995). The UKWIR method assumes past performance is a good indicator of future performance and we use information on previous outage events. For this plan, we have based outage on data recorded between 1998 and 2016.

Outage allowances are assessed at resource zone level. We produce outage assessments for the dry year annual average scenario for both the Grid and East SWZs. This section provides a summary of our outage assessment. Further technical detail is provided in a supporting Outage Assessment Technical Report, which has been provided to the Environment Agency and available on request.

The Grid SWZ outage assessment includes unplanned events, planned events, reservoir safety events and licence margins. The East SWZ outage assessment includes unplanned and planned events only. As the East SWZ is a small zone relying on a river abstraction with support from a spring source, there are no reservoirs to include in the assessment. Licence margins are only relevant to one river abstraction in the Grid SWZ.

We calculate outage for unplanned events, planned events and reservoir safety events using a probabilistic software model. Data on events is derived from a Yorkshire Water database known as KAM (Key Asset Management). Events that impact on our assets are recorded on this database, including any reduction in the amount of water an asset can produce.

3.17.1 Unplanned outage

Unplanned outages are unforeseen events which occur with sufficient regularity that the probability and severity of the outage event can be predicted from previous events. The UKWIR methodology defines the following categories as unplanned outages: pollution of source, turbidity, nitrates, algae, power and system failure.

The methodology prescribes a probabilistic approach to assessing unplanned outage, which considers the duration and magnitude of previous outage events. We modified this approach to include frequency of events to make an allowance for the risk of the event reoccurring.

We obtain data on previous unplanned outage events from the KAM database and discussions with operational staff. From this data, we derive minimum, average and maximum distributions of duration, magnitude and frequency for individual outage events. The distributions are considered for each month of the year as some outage issues, such as algae include a seasonality factor.

We input the distributions for each event into the outage model. The model uses probabilistic methods to combine outage data for individual events and determines monthly unplanned outage allowances for each water resource zone. The monthly outage results for each zone are provided for a range of certainty levels between zero and 100%. The outage allowance increases with increasing levels of certainty.

It is not economical to plan for a 100% level of certainty. As in previous plan submissions, we have chosen to plan for the median or 50% level of certainty.

3.17.2 Reservoir safety outage

Statutory requirements of reservoir maintenance require reservoirs to be periodically drawn down for inspection and repairs. Around 45% of supply to the Grid SWZ is from reservoirs in our region and outage in this zone includes an allowance for loss of yield due to reservoir safety schemes. The East SWZ assessment does not require an outage allowance for reservoir safety as this zone contains no impounding reservoirs.

We have calculated a total outage allowance for reservoir safety schemes using the outage probabilistic model. The data used in the model is based on loss of yield recorded in Yorkshire Water databases for previous drawdowns.

The model calculates reservoir safety outage for each month of the year over a range of certainties between zero and 100%. As with unplanned outage, we plan for the 50% level of certainty.

3.17.3 Planned outage

We assess outage due to planned events for both water resource zones. Planned outages result from a requirement to maintain the serviceability of assets.

Maintenance of assets, such as water treatment works, river water abstraction works and raw water transmission mains, has the potential to lead to a temporary reduction in deployable output.

We schedule most maintenance for periods when demand is low and alternative sources can be made available. However, this is not always possible and we have not included any planned outage as a result of capital schemes to be delivered in AMP7. A number of schemes that have resulted from our Drinking Water Quality programme will temporarily reduce the output of several water treatment works while the work is being implemented. We have not included any additional outage allowance for these schemes as the work will be phased and storage managed to minimise the actual outage. The impact of the water quality schemes on outage in the final planning scenario is discussed in Section 12.1.

Additional outages will also occur as a result of other general maintenance schemes, for example, replacing pumps at river intakes or rapid gravity filters at water treatment works. In most cases the schemes will be delivered when there will be no or minimum impact on the supply demand balance. However, some planned outage will result from these schemes.

Planned outage for future events is dependent on the feasibility of delaying the schemes in a dry year when the water is needed. As water availability and the timing of a dry period are unknown, it is not possible to provide an accurate estimate of planned outage. It will range from a value of zero to a yield specific to a planned event.

To provide an estimate of future planned outage we have used a probabilistic model, based on previous events recorded in the Yorkshire Water database. We derive information from the KAM database on the duration and magnitude of individual maintenance events that led to an outage.

3.17.4 Licence margins

The Grid SWZ includes an outage allowance due to licence margins. Licence margins represent the difference between volumes theoretically available under the abstraction licence conditions and volumes that are operationally available.

A licence margin outage is applied to one river abstraction in the Grid SWZ where a reservoir release is used to support the abstraction at times of low flow. When river flows increase above the critical level there is a time lag between the recovery and stopping the release, and some water is lost due to over support from the reservoir.

The licence margin allowed for at this site is 1Ml/d and is the same as that reported in previous WRMPs.

3.17.5 Total outage

The total outage for each resource zone is the sum of the outage components described above. We calculate total outage for each month of the year but base the outage allowance on the average for April to September. This represents the drier months of the year.

Table 3.11 shows the outage results for the two water resource zones. We assume outage will remain constant throughout the planning period.

Table 3.11 Resource zone outage

Water Resource Zone	Planned outage Ml/d	Unplanned outage Ml/d	Reservoir safety outage Ml/d	Licence margins outage Ml/d	Total outage Ml/d
East SWZ	-	0.13	-	-	0.13
Grid SWZ	6.61	35.88	8.91	1.0	52.40

The East SWZ total outage is 0.13Ml/d. No maintenance or capital schemes are planned that could lead to planned outage in this zone. The East SWZ planned outage is therefore zero, and the total 0.13Ml/d outage for this zone is due to unplanned outage.

Most of the East SWZ outage is due to outages at the river source. Turbidity has been a problem at the spring source and the river intake has in the past experienced outages due to turbidity, water quality and pollution issues. Water from the spring source is stored at the water treatment works and can be used for supply until outage events recover.

The Grid SWZ total outage is 52.40Ml/d. This is made up of unplanned outage, planned outage, reservoir safety outage and licence margins. Figure 3.8 shows the percentage each outage category contributes to total outage value for the Grid SWZ.

Figure 3.8 Grid SWZ total outage percentages by category

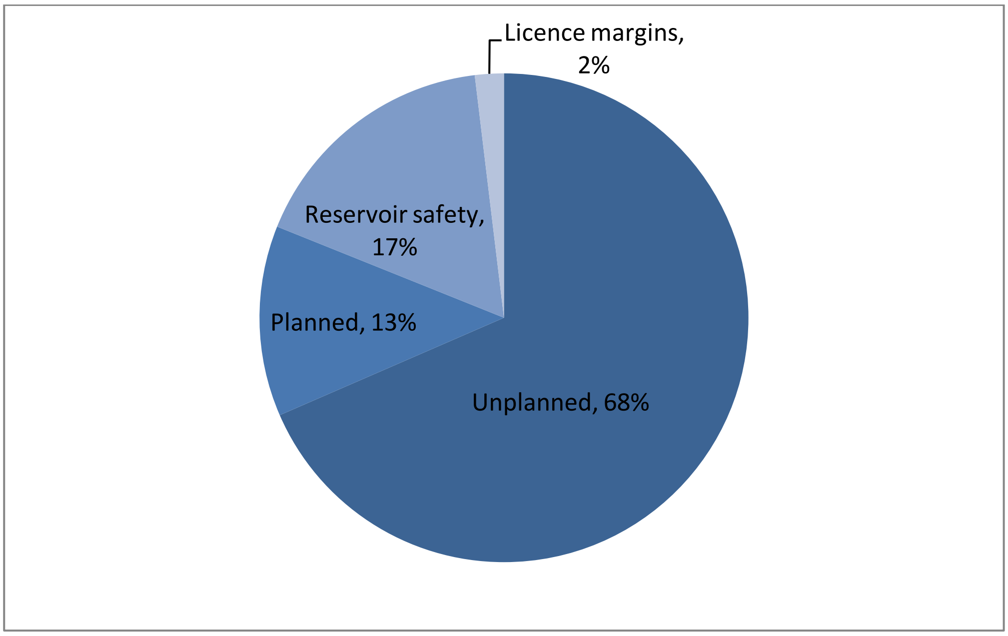
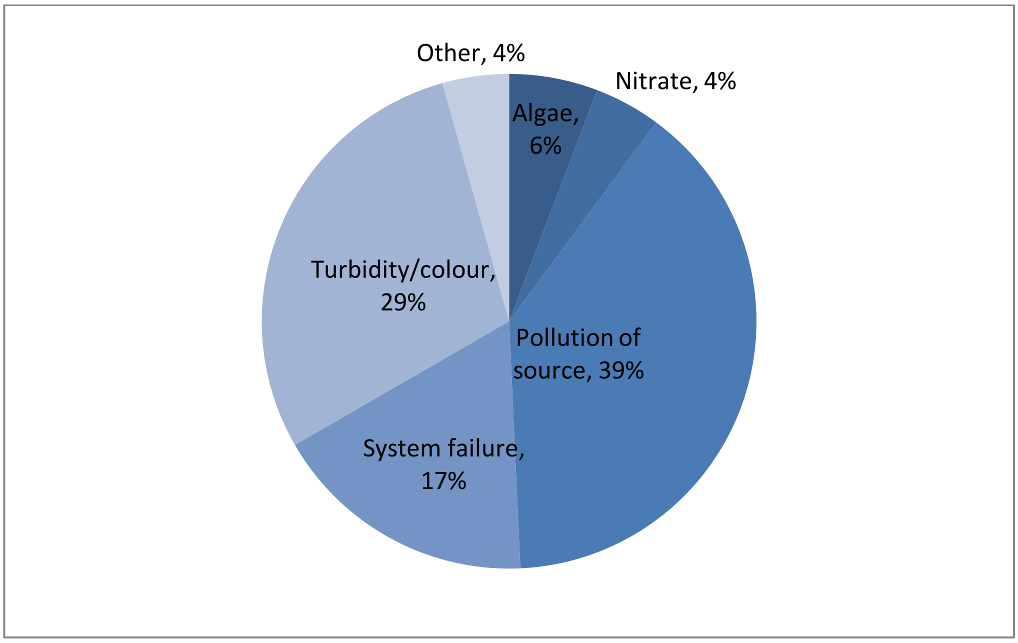


Figure 3.9 Grid SWZ unplanned outage percentages by type of event



Unplanned outage makes up the largest proportion (68%) of the Grid SWZ allowance. Nitrates, algae, source pollution, turbidity and system failures can all lead to unplanned outage events. Figure 3.9 shows a breakdown of unplanned outage by type of event in the Grid SWZ.

These events are not easy to avoid as the majority are the result of naturally occurring events or pollution events. To reduce the impact of such events we can blend the water with high quality water or improve the treatment processes. However, this is not always possible, and outages can occur where we need to stop or reduce the use of a source until the quality improves.

System failure makes up 17% of unplanned outage and is a result of infrastructure breaking down at water treatment works or abstraction sites. These outages are often a result of poor water quality impacting on the works. This often results in maintenance being required, for example, cleaning of filters.

A number of the options considered in our options appraisal could help mitigate the risk of outages and this is considered in Section 10.3.2.

3.18 Process losses

The supply demand balance includes allowances for raw water losses, treatment works losses and operational use. These are an allowance for the volume of water that is lost during the process of abstracting and treating water before it is put into supply.

We do not have any non-potable supply transfers between zones or to adjacent water companies. There are some non-potable supplies to farm properties, but these volumes are minor and have been excluded from the WRMP19.

3.18.1 Raw water losses and operational use

Raw water losses and operational use occur between the point of abstraction and the treatment works. There are no raw water losses or operational use recorded for the East SWZ.

Our Grid SWZ includes raw water operational use due to cleaning raw water mains and valve testing at reservoirs. Cleaning occurs every two to three years on our largest raw water transmission systems within the Grid SWZ, where sedimentation results in a loss of supply capacity. Other raw water mains are cleaned on an ad hoc basis. Raw water is released from reservoirs twice a year during valve testing, a legal requirement for reservoir safety.

We assume 0.25Ml/d is lost due to raw water operational use for cleaning mains in the Grid SWZ. An assumed loss due to reservoir valve testing is calculated annually. For the WRMP19 we base reservoir valve testing losses on the average volume released per a year during August and September.

3.18.2 Treated water losses and operational use

Treated water losses and operational use occur during the process of treating water before it is put into supply. We have assessed the amount of water lost during the process of cleaning filters, often referred to as wash water, and the water lost through sludge disposal. Within Yorkshire Water, the percentage of water lost through these varies considerably from site to site.

Table 3.12 shows raw water losses, treatment works losses and operational use for each water resource zone, based on recent data, recorded between 2013/14 and 2016/17.

We have assumed these losses will remain consistent throughout the 25- year planning period in both zones.

Table 3.12 Raw water losses, treatment works losses and operational use

Water Resource Zone	Grid SWZ	East SWZ
Treated water losses - wash water (Ml/d)	4.26	1.71
Treated water losses - sludge to sewer (Ml/d)	14.44	0
Raw water operational use - mains cleaning (Ml/d)	0.25	0
Raw water operational use - valve testing (Ml/d)	0.79	0
Total treated water operational use (Ml/d)	19.73	1.71

3.19 Water available for use

Outage, raw water losses, treatment works losses and operational use are deducted from deployable output to provide the water available for use (WAFU) from our own sources of supply for each water resource zone. Table 3.13 summarises the impact of these losses on the deployable output in the 2015/16 base year.

Table 3.13 Impacts of Grid SWZ outage and process losses on deployable output

Water Resource Zone	Grid SWZ	East SWZ
Base year deployable output (Ml/d)	1,391.10	14.00
Outage (Ml/d)	52.40	0.13
Process losses (Ml/d)	19.73	1.71
Base year WAFU (Ml/d)	1,318.97	12.16

3.19.1 Impacts of water transfers on water available for use

The WAFU from our own sources is then adjusted for imports and exports to give the total water available for use. This is shown in Table 3.14 for the base year of each zone. The total WAFU is the total supply that can be compared against demand and headroom to determine if there are any deficits in the supply demand balance.

Table 3.14 Impacts of East SWZ outage and process losses on deployable output

Water Resource Zone	Grid SWZ	East SWZ
Base year WAFU (Ml/d)	1,318.97	12.16
Base year imports (Ml/d)	51.87	0.00
Base year exports (Ml/d)	0.31	0.00
Base year total WAFU (Ml/d)	1,370.53	12.16

4 Demand forecast

This section describes how we have calculated how much demand for water there will be, now and in the future – our demand forecast. We explain what we have included in our forecast, and how we have considered the effects of factors such as increasing population, new development, water that is lost or wasted – for example through leakage – and changing patterns of use.

4.1 Introduction

A 25-year demand forecast has been produced to cover the period 2015/16 to 2044/45. This forecast is based on assumptions about how the key factors influencing water demand will change over the plan period. We have also extended our forecast of demand an additional 15 years to ensure we have resilience into the future.

This section provides a summary of our methodologies and modelled outputs. Further technical detail is provided in a supporting Demand Forecasting Technical Report, which has been provided to the Environment Agency and is available on request.

The demand forecast is produced for our two water resource zones, the Grid SWZ and the East SWZ, individually and the Yorkshire Water region.

A conservative approach is taken to forecasting demand (dry year annual average), which includes assumptions of climate change and dry year uplift as standard.

The demand forecast has been prepared in line with the best practice methodology set out in the *WRMP19 Methods - Household Consumption Forecasting (*UKWIR, 2016*); Population, household property and occupancy forecasting* (UKWIR, 2016); and the *Water Resources Planning Guideline* (Environment Agency and Natural Resources Wales, 2017).

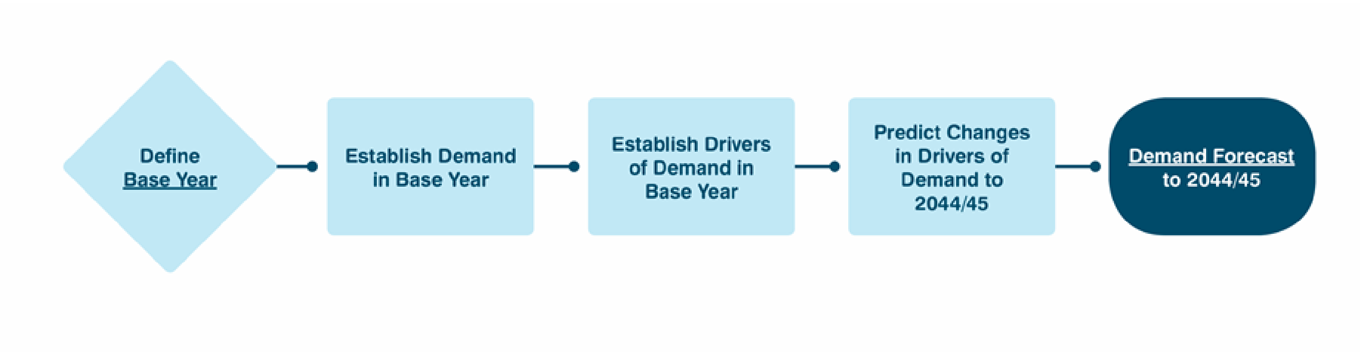
The Environment Agency guidance includes an additional household demand forecasting report *Integration of behavioural change into demand forecasting and water efficiency practices* (UKWIR, 2016). We have not used this report in developing our forecast as we do not consider it to be a robust methodology. The findings presented in the report are based on water usage data from a very small sample of 60 properties which were then subdivided into cohorts, with limited representation of customers either regionally or nationally. The shortcomings of this report are recognised by the authors and we do not consider the robustness of our household demand forecast would be improved by its inclusion.

The report, however, does provide useful insight into the range of water use behaviour by different customer cohorts. This is useful information for developing targeted water efficiency initiatives for household customers.

To develop our demand forecast the first step is to establish demand in the base year (2015/16). We then consider the key factors that could influence demand and use modelling to predict their impact in the future. Key drivers of future demand include population growth, changing household demographics, economic prospects and demand management, such as water efficiency and leakage reduction.

The methodology can be simplified to the process summarised in Figure 4.1.

Figure 4.1 Summary of demand forecasting methodology



The methodology includes the forecast of water use by our four customer groups, which are defined by property type. These categories are defined in Section 4.3.1 and comprise:

- unmeasured households;

- measured households;
- unmeasured non-households; and,
- measured non-households.

Each of the property categories have their own set of demand drivers and assumptions for future growth rates. These include population projections, households switching to paying by meter (domestic meter optants), new connections and the economic environment.

In addition, there are also minor components of demand, which include distribution operational use (water used by Yorkshire Water for operational purposes) and water taken unbilled. Leakage also forms part of the demand forecast.

There are various terms used in relation to demand for water, which include different components. The main terms used in this report and the planning tables are defined as follows:

- **Consumption** - the water used by a property. It includes the volume of water used and meter under registration but excludes supply pipe leakage.
- **Total Water Delivered** - comprises the volume of water supplied from treatment works, less the volume the water company uses (distribution system operational use) or is lost through the company's pipes (leakage).
- **Distribution Input** - the average amount of drinking water entering the distribution system to be supplied to consumers in an appointed water company's area of supply. This is essentially total demand for water as it includes consumption, leakage, water taken unbilled and distribution system operational use.

The following key data sources and assumptions have been included in the forecast:

- Yorkshire Water historical operational data;

- plan based population and household projections incorporating data from local planning strategies from Local Authorities;
- the effect of climate change on demand for water;
- micro-component based household demand forecast; and,
- macro-economic based non-household demand forecast.

4.2 The base year

The base year has been defined for the WRMP19 as 2015/16, which covers the year April 2015 to March 2016.

We calculated the water balance for the base year. This compares the measured volume of water into supply from our treatment works (distribution input) with the sum of the measured and estimated components of demand. The reported distribution input exceeds the water that can be accounted for, therefore there is an adjustment for this surplus water. The maximum likelihood estimation (MLE) technique has been used to allocate this discrepancy across all components based on the accuracy of measurement. For example, metered volumes are more accurate than volumes obtained from estimates and assumptions, and therefore the accuracy bands and volume adjustment around these components are smaller.

The water balance for the base year has been adjusted in line with new guidance from UKWIR entitled *Consistency of Reporting Performance Measures* (UKWIR, 2017). This affects the water accounted for and therefore the amount of surplus water that needs to be incorporated into the MLE adjustment. The amended assumptions will be incorporated into future annual reporting of total leakage.

The adjusted MLE table is presented in Table 4.1. The right-hand column (post MLE) is the base year data used as the basis for the demand forecast.

Table 4.1 Regional maximum likelihood estimation table

2015/16	Base (Ml/d)	Accuracy (+ or -)	Confidence Range	% of Total Variance	Adjust-ment	Final figures rounded	Post MLE (Ml/d)
Measured Households	252.50						**253.98**
Consumption	*225.00*	*2%*	*9.00*	*0.03*	*0.84*	*225.84*	
Supply pipe leakage internally metered	*15.60*	*5%*	*1.56*	*0.01*	*0.15*	*15.74*	
Supply pipe leakage externally metered	*7.25*	*5%*	*0.73*	*0.00*	*0.07*	*7.32*	
Meter Under-registration	*4.65*	*50%*	*4.65*	*0.02*	*0.44*	*5.08*	
Measured Non-Households	267.06						**269.33**
Consumption	*250.66*	*2%*	*10.03*	*0.04*	*0.94*	*251.60*	
Supply Pipe Leakage	*2.50*	*5%*	*0.25*	*0.00*	*0.02*	*2.53*	
Meter Under-registration	*13.90*	*50%*	*13.90*	*0.05*	*1.30*	*15.20*	
Unmeasured Households	454.45						**463.14**
Consumption	*400.82*	*10%*	*80.16*	*0.30*	*7.51*	*408.33*	
Supply Pipe Leakage	*45.61*	*5%*	*4.56*	*0.02*	*0.43*	*46.04*	
Meter Under-registration	*8.02*	*50%*	*8.02*	*0.03*	*0.75*	*8.77*	
Unmeasured Non-Household	2.57						**2.66**
Consumption	*1.89*	*25%*	*0.95*	*0.00*	*0.09*	*1.98*	
Supply Pipe Leakage	*0.67*	*5%*	*0.07*	*0.00*	*0.01*	*0.68*	
Water Taken Illegally	17.82	50%	17.82	0.07	1.67	19.49	**19.49**
Water Taken Legally	11.36	50%	11.36	0.04	1.06	12.43	**18.20**
Void Supply Pipe Leakage	5.51	25%	2.76	0.01	0.26	5.77	
Distribution System Operational Use	1.65	50%	1.65	0.01	0.15	1.80	**1.80**
Total Water Delivered (excl. DOU)	1,011.27					1,026.80	**1,026.80**
Distribution Losses	211.97						**216.12**
Losses in DMAs	*170.37*	*5%*	*17.04*	*0.06*	*1.42*	*171.80*	*171.80*
Trunk Main and Service Reservoir Losses	*41.60*	*40%*	*32.56*	*0.11*	*2.72*	*44.32*	*44.32*
Distribution Input	1,249.92	2%	50.00	0.19	-4.69	1,245.23	**1,245.23**
Water accounted for	*1,224.89*						*1,245.22*
Difference	*25.03*						
Total Supply Pipe Leakage	77.15						**78.08**
Total Leakage	289.13					5.57	**294.70**

`

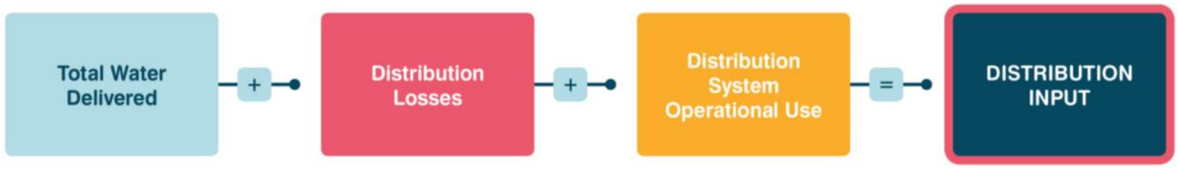
The adjusted base year data was then rebased for the dry year annual average scenario as detailed in Section 4.3 below.

4.3 Accounting for demand in the base year

The base year demand for the dry year annual average demand forecast is based on the annual water balance data with the MLE adjustment (set out in Section 4.2) and an uplift for dry year (to be discussed in Section 4.3.1).

The total demand for water is termed distribution input and is made up of several elements of demand as shown in Figure 4.2.

Figure 4.2 Components of distribution input



In this section of the report, the base year distribution input is split into its component parts, which then allows us to forecast future changes to each of these components and therefore future demand.

4.3.1 Total water delivered

Total water delivered comprises the water delivered to each property category plus an estimate of water taken unbilled.

Water delivered to customers can be defined as the volume of water consumed by customers (including meter under registration where appropriate), and customer supply pipes leakage.

Meter under registration is the volume of water that is not recorded by water meters due to an error in recording as meters age and wear. We estimate meter under registration values for household and non-household meters.

The amount of water delivered to each property category depends on the number of properties in that category and, in the case of household properties, the population associated with those properties.

We therefore need to establish the number of properties, estimated population (if appropriate) and water consumption for each of these property categories.

Properties

The number of properties in each customer category in the base year is extracted from our billing file.

The occupied properties are divided into four categories:

- **Measured households -** domestic properties with a meter (meter can be internal or external).
- **Unmeasured households -** domestic properties without a meter that pay for water based on the rateable value of the property.
- **Measured non-households** - commercial properties with a meter.
- **Unmeasured non-households -** commercial properties without a meter.

The other two property categories, household voids and non-household voids, are properties that are registered as empty on our billing file.

Population

We estimate population for all four occupied property categories: measured household, unmeasured household, measured non-household and unmeasured non-household.

For households, population is derived from known property numbers multiplied by an occupancy rate for that category.

Previously, we have obtained estimated occupancy data from limited surveys of household customers. For the WRMP19, occupancy rates have been provided by CACI Ltd for every household on the billing file in December 2016.

The occupancy rates used in the base year are detailed in Table 4.2 below.

Table 4.2 Occupancy rates for the different property categories in the base year

	Measured Households	Unmeasured Households	Unmeasured Non-Households (mixed use)
Grid SWZ	2.26	2.62	2.62
East SWZ	1.96	2.21	2.21

The population split between the two resource zones was also revised based on these updated occupancy rates.

The unmeasured non-household population includes mixed-use properties which are primarily domestic use, for example flats over small shops. There are approximately 1500 mixed-use properties on our billing file, with an estimated population in the region of 4,000. These properties are assumed to have the same occupancy rates as unmeasured households.

The measured non-household population is taken as the communal population obtained from Office for National Statistics (ONS) census data. This includes prisons, nursing homes, university halls of residence and Ministry of Defence facilities. In Yorkshire, the communal population in the base year is 77,613. This number excludes the population of a military garrison in North Yorkshire which has its own water supply.

Clandestine and hidden population

In addition to the population recorded in the ONS census, there is a population known as 'clandestine and hidden' which, for a number of reasons, is not included within this data. Estimation of this clandestine and hidden population is an important component of the water balance calculation, as any population that remains unrecorded potentially increases the unaccounted for water.

We commissioned demographic consultancy Edge Analytics Ltd to provide an estimate of the clandestine and hidden population for each water resource zone (*Clandestine & Hidden Populations,* Edge Analytics, 2017). Edge Analytics provided

estimates of the four sub-populations that are considered to sit outside the census population:

- **Irregular migrants**, which typically refers to the stock of migrants in a country who are not entitled to reside there.
- Edge Analytics used a report produced by London School of Economics (LSE) *Economic impact on London and the UK of an Earned Regularisation of Irregular Migrants in the UK* (Gordon et al, 2009) which provides a low, medium and high estimate of irregular migrants in the UK. An estimated 70% of this population is in London. Edge Analytics have disaggregated the remaining 30% into local authority areas that are fully or partially within Yorkshire Water's operational boundaries. This was done in proportion to the average annual National Insurance Number registrations recorded to non-EU foreign nationals between 2012 and 2016, relative to the total for the rest of the UK. The estimates were then rescaled in recognition that the LSE report estimates are likely to have increased since 2007.
- **Short-term residents**, which refers to someone who is only resident in the UK for between 1 and 12 months.
- There are two subtle sub-categories within this category, which includes short-term residents who stayed for between 1 and 12 months to work or study, and short-term migrants who stays for a period of between 3 and 12 months. Edge Analytics used ONS census data from 2011 on short-term residents and annual statistics on short-term migrants to develop low medium and high estimates of the short-term resident population.
- **People staying at a second address**, which include armed forces bases, addresses used by people working away from home, a student's home address, the address of another parent or guardian or a holiday home.
- Edge Analytics used second address statistics from the 2011 Census to form the basis of this population estimate. Additional assumptions around the number of nights these addresses are used were

incorporated to provide low, medium and high scenarios for an equivalent full-time population.

- Domestic and foreign visitors to friends and relatives.
- While most visitors and tourists are likely to be captured at tourist sites, in hotels and other commercial accommodation, a proportion will not be captured. These are day visitors to friends and family (domestic visitors) and overnight stays with friends and family (domestic and foreign visitors).
- Edge Analytics used data from the 2015 '*GB Day Visitor Survey*' and the 2014 '*GB Tourist Survey*', published by Visit England, to develop low, medium and high estimates for an equivalent full-time population.

The low, medium and high estimates of population in the four clandestine and hidden categories for our total water supply area are shown in Table 4.3.

Table 4.3 Clandestine and hidden population estimates - water supply area

Clandestine and Hidden Population	Population Estimates		
	Low	Medium	High
Irregular migrants	13,307	20,816	29,834
Short term residents	13,497	20,497	31,045
Second addresses	1,936	4,851	7,766
Visiting friends and relatives	17,113	28,522	39,931
Total	45,852	74,687	108,576

We have used the central 'medium' estimate of population in our WRMP19. The estimated population in our two resource zones is shown in Table 4.4 below.

Table 4.4 Medium clandestine and hidden population used in WRMP19

	Irregular Migrants	Short-term Residents	Second Addresses	Visiting Friends and Relatives	Total
East SWZ	14	43	149	356	563
Grid SWZ	20,802	20,454	4,702	28,166	74,124
Region	20,816	20,497	4,851	28,522	74,687

We used the number of households in the measured and unmeasured household categories in the base year to split this population between the two household categories.

Consumption

Consumption is defined as the water used by a property. This includes the volume of water use and meter under registration but excludes supply pipe leakage.

Household consumption

Measured households

The volume of water delivered to measured households is obtained from meter reading data from our company billing system.

To calculate water consumption for these properties we subtract an estimate of supply pipe leakage from the measured volume and include an additional volume for estimated meter under registration.

The total consumption of measured households is divided by the estimated population of these properties to give a measured per capita consumption (PCC) value.

For the base year, we have revised our estimated measured PCC taking account of our revised measured household population estimate determined for the WRMP.

Due to an increase in estimated measured household population, the measured household PCC has decreased slightly.

Unmeasured households

Unmeasured households are properties where water charges are based on the rateable value of the property rather than a metered supply. The consumption of water by these properties is estimated from our Domestic Consumption Monitor (DCM). The DCM consists of, on average, 1000 unmeasured properties which have logged meters installed but which continue to pay for water on an unmetered basis. The properties have been selected to be representative of our unmeasured property base, including property type, number of occupants and geographic location. Consumption data from all properties on the survey is obtained daily through a telemetry system. From this we obtain the average daily volume of water used by our unmeasured household customers, known as unmeasured household PCC.

Household meter under registration

As described earlier, meter under registration is the volume of water that is not recorded by water meters due to an error in recording as meters age and wear. For metered and unmetered households, we assume a meter under registration value of 2%. This is based on previous flow testing of meters, and relative age and throughput of billing meters and meters at properties on our domestic consumption monitor.

The base year household PCCs are then uplifted to create the dry year annual average scenario. This uplift is discussed in at the end of this section.

Clandestine and hidden population water use

Previously we added the estimated water use by the clandestine and hidden population onto our estimated unmeasured household consumption as a set volume.

For this plan, the clandestine and hidden population is divided between the measured and unmeasured household categories, as discussed previously. For the measured households, we assume that the consumption of this population is captured by the water meters at these properties. Therefore, no additional volume is

added to this category. For the unmeasured households, the clandestine and hidden population are assumed to have the same PCC as the rest of the unmeasured household population. Their consumption is therefore calculated in the same way as the rest of the unmeasured household population.

Non-household consumption

The volume of water consumed by non-household properties is derived from billed volumes in 2015/16. This data was obtained from our non-household billing file for the base year. In the future, following the opening of the non-household retail market, this information will be obtained from the central market operating system (CMOS).

Non-household meter under registration

We also add an estimate of meter under registration onto the measured non-household volume obtained from the billing file to account for under recording due to meter aging and wear.

Previously we have used an industry average meter under registration estimation for measured non-households. However, as part of our data improvement plan we have determined a Yorkshire Water specific value for meter under registration. Six DMAs were selected which contained predominantly non-household properties. The 588 non-household properties within these DMAs provided a wide range business types, including service and non-service industries, farms, a university and city centre premises, covering many industry classifications and average daily consumption bands.

An assessment of both meter under registration and appropriateness of the existing meter size was carried out on all meters at these properties. The process was carried out to ensure any potential double counting of the impact of meter age and meter size on meter under registration was eliminated.

Statistical analysis of the meter under registration due to meter age and size in the sample was carried out and applied proportionately across all our non-household meter stock. This provided a meter under registration value for measured non-households of 5.49%.

Void properties

Both household and non-household void properties have no population associated with them and therefore they do not have any consumption. The only water delivered to these properties therefore is supply pipe leakage, which is not part of consumption.

Supply pipe leakage

Supply pipe leakage is defined as leakage from pipes located within property boundaries, i.e. between our main and the customers' taps. This applies to all property types.

Within the measured households category, the meters can be positioned either internal or external to the property boundary, which makes a difference in terms of supply pipe leakage rate. The position of the meter is recorded in our billing file.

If the meter is located externally to the boundary, any leakage on the supply pipe between the meter and the property will be registered by the meter. If the supply pipe leakage is significant, this will result in a higher than usual metered volume and bill value.

If the meter is located internally within the property any leakage on the supply pipe between the boundary and the property will not be registered on the meter and will not impact the measured volume and bill value.

As a result, the time taken for supply pipe leakage on an externally metered property to be identified is likely to be less than for an internally metered property, due to the abnormally high bill value. Consequently, the estimated supply pipe leakage rate for externally metered properties is higher than the estimated value for internally metered properties.

The base year supply pipe leakage rates are calculated from the total leakage reported to Ofwat as part of Annual Performance Reporting.

Water taken unbilled

Water taken unbilled includes water taken legally and illegally that is not paid for by the customer. As this water use is unbilled the volume has been estimated using

best available information. We estimate the volume of water taken unbilled annually as part of our water balance calculation. The total estimated volume remains relatively constant at approximately 30Ml/d (2% of distribution input) each year.

Water taken legally includes water used for firefighting and training, standpipe use, and unbilled water used at our own operational and office sites.

We provide a free potable water supply to 320 properties in Yorkshire. Of these, 85 are classed as farms. In many cases these are historic agreements drawn up in return for access to private land (for example, a raw or treated water main crossing private land). Water use by these properties has been estimated based on average unmeasured household use and published data on water use at small and medium livestock farms. In 2015/16 the estimated water used by these properties was approximately 1Ml/d.

On average 900 to 1000 metered standpipes are on hire to contractors each day. The metered volume recorded for the standpipes is collected monthly. The average metered volume for 2015/16 was 0.36Ml/d.

Each year we receive data from the four Fire and Rescue Services in Yorkshire. These detail the number of primary and secondary fires attended, and where water has been used for firefighting. In 2015/16, 6,500 primary and 10,000 secondary fires were attended. Detailed analysis of historic data and water-using equipment used for firefighting has provided an estimate of average water use at primary and secondary fires. This data is used to estimate the annual water used for firefighting in Yorkshire. In 2015/16 this was estimated to be approximately 1Ml/d.

Water use at all Yorkshire Water operational and office sites is metered but not billed. In 2015/16, the metered water use at Yorkshire Water sites was 4.5Ml/d.

The total volume of water taken legally unbilled in 2015/16 was 11.36Ml/d. Our adjusted MLE value (12.43Ml/d) has been used for the base year volume.

Water taken illegally includes occupied voids, illegal hydrant use and illegal connections.

At any one time, there are approximately 100,000 void household properties on our billing file. These properties are visited by Yorkshire Water staff to determine if the void status is valid. Approximately 45% of properties visited are found to be occupied. Assumed duration of occupancy, average household occupancy rate and PCC are used to estimate water use by these customers.

For non-household customers, an automated process in our billing file identifies void properties with recorded water use or frequent change of occupier. An average non-household consumption volume is used to estimate water use at these properties.

Additionally, an income protection team has been in operation for several years, identifying water-using properties that are not on our billing file.

The estimated water use by illegal connections and occupied voids is in the region of 12Ml/d. We also estimate illegal hydrant use to be approximately 4Ml/d.

The total volume of water taken illegally unbilled in 2015/16 was 17.82Ml/d. Our adjusted MLE value (19.49Ml/d) has been used for the base year volume.

Dry year effect

In accordance with the *Water Resources Planning Guideline* (Environment Agency and Natural Resources Wales, 2017), the demand forecast has been prepared for a dry year annual average scenario.

To determine demand in a dry year we have used methodologies presented in the report *WRMP19 methods – Household Consumption Forecasting* (UKWIR, 2015).

Weather affects household water use. In general, water use increases during periods of dry warm weather due to increased garden watering and personal washing. Therefore, the most accurate approach to estimating dry year demand is to analyse historic weather effects on household level consumption data.

Historic demand and weather data were analysed to determine annual average demand for a typical 'normal' year and typical 'dry' year, and to develop weather-demand models. This analysis was then used to adjust consumption in our base

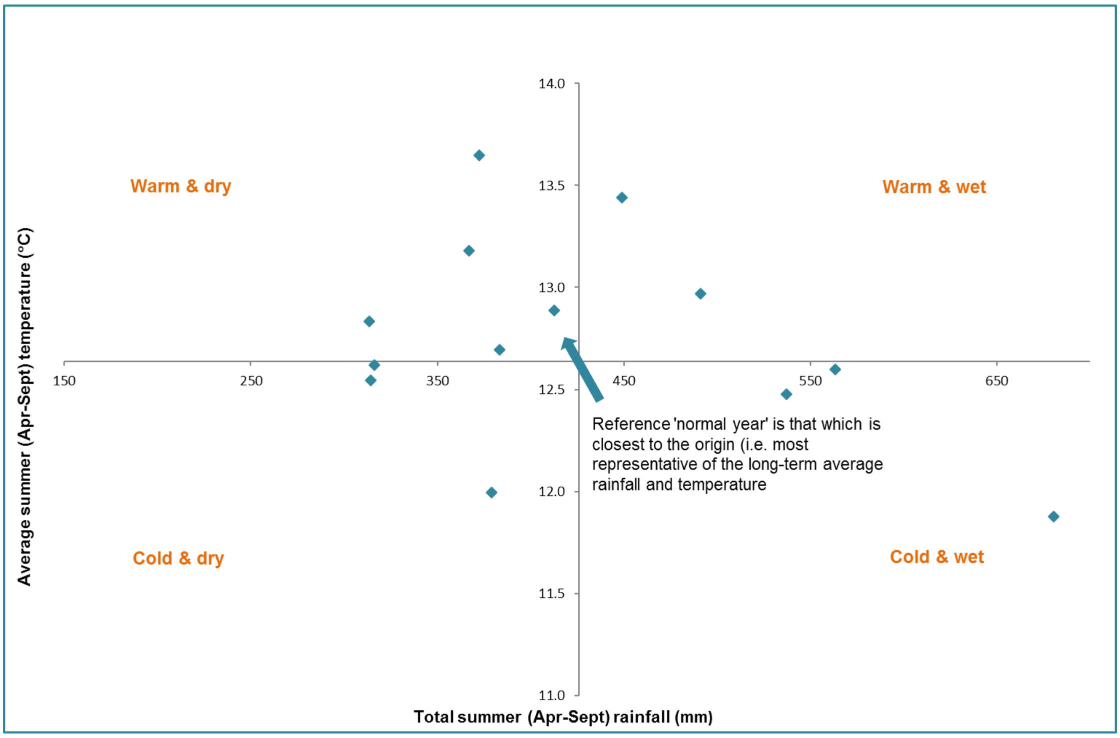
year (2015/16) to a dry year scenario by application of an uplift factor to average PCC.

Two approaches presented in the *Household Demand Forecasting* report were used to develop a weather-demand model. These were used to estimate a dry weather uplift of PCC and dry year and normal year adjustment factors.

The two approaches were quadrant analysis, which uses long-term total summer rainfall and average summer temperature to identify potential reference 'normal' and 'dry' years; and construction of a regression model to describe the relationship between demand and weather parameters.

Figure 4.3 shows quadrant analysis used to determine the reference 'normal' year. A plot of long-term total summer (April to September) rainfall (mm) and temperature (ºC) for the period 1993 to 2016 provides a temperature versus rainfall quadrant. The reference normal year is selected as that closest to the origin, i.e. closest to the long-term average weather.

Figure 4.3 Quadrant analysis to determine reference normal year



Quadrant analysis was repeated using weekly average summer temperature and total weekly rainfall for the period April to September. This identified candidate dry

weeks as those plotted within the 'warm and dry' quadrant. Listing these in chronological order identified blocks of consecutive dry weeks for use in the estimation of the dry year annual average adjustment factor.

To develop a regression model, average weekly PCC for the period April 2009 to October 2016 was modelled against weather variables, including average daily soil moisture deficit, average daily sunshine hours, average daily temperature, average daily rainfall and total weekly active evaporation.

The model was then used to estimate how demand varies with weather characteristics and to calculate normal year and dry year adjustment factors through a hindcast methodology.

The quadrant analysis and hindcast modelling were used to determine normal year and dry year adjustment factors.

The analysis showed that the base year was not a 'normal' year in terms of weather and household demand. Therefore, an uplift factor was determined to convert from base to dry year demand for a dry summer (April to September).

The calculated uplift factors to be applied to household demand in the base year to give a dry year annual average demand are presented in Table 4.5 below.

Table 4.5 Normal and dry year uplift factors

Description	Uplift factor	% uplift
Base to Normal	1.008	0.806
Normal to Dry	1.034	3.427
Base to Dry	1.038	3.825

As the dry year uplift analysis was carried out using data for the summer months, to produce an uplift applicable for the whole year the remaining six months (October to March) needs to be included, when no uplift is applied. Consequently, the dry weather uplift for the whole year is assumed to be 50% of the estimated six months' value (1.913%).

PCC differs between measured and unmeasured properties. Therefore, the estimate of the adjustment from base year to dry year is allocated pro rata as per the annual proportional split of total volume (Ml/d) between measured and unmeasured properties.

4.3.2 Distribution losses

Distribution losses are total leakage less total supply pipe leakage. Total leakage for the base year, taken from our adjusted MLE table, was 294.7Ml/d and total supply pipe leakage was 78.0Ml/d. Therefore, distribution losses were 216.7Ml/d.

Leakage is explained in more detail in Section 5. Briefly, it comprises:

- Service reservoir leakage and trunk main leakage (44.65Ml/d in base year); and
- Leakage in distribution management areas (DMAs), of which 31.17% is estimated to be supply pipe leakage.

4.3.3 Distribution system operational use

The final component of the base year distribution input is distribution system operational use. This is water we use for activities such as mains flushing, service reservoir cleaning and water quality testing at our water treatment works and in distribution (from our water mains and service reservoirs and from customers' taps). In our base year, we cleaned 180 service reservoirs and treated water storage tanks, collected 74,000 treated water samples for water quality testing and carried out over 6,000 mains flushing operations. The estimated water use for this activity in 2015/16 was 1.8Ml/d.

4.3.4 Water resource zones split

The water resource planning tables that support this WRMP19 are completed at a water resource zone level. Therefore, all the elements of the demand forecast discussed above are split between the Grid SWZ and the East SWZ.

The water delivered to each property category is based on the number of properties or population in each zone. For the other components, such as water taken unbilled and distribution system operational use, zone ratios were used to split the volume of water between the water resource zones.

4.4 Background to forecast changes in demand to 2044/45

The forecast demand to 2044/45 is built up from forecast changes in each component of distribution input.

4.4.1 Water delivered

The forecast water delivered is driven by our own policies; changes to property numbers, population and consumption; and climatic variations.

Yorkshire Water policies

The first changes that affect the forecast water delivered, relate to our own policies. We have a policy of demand management, through both reduction in customers' water use by metering and water efficiency, and through reduction in leakage on our own distribution system.

Metering strategy

The household properties which opt to switch to a metered supply are known as domestic meter optants (DMOs).

We promote domestic meters in our communication to customers through billing and on our website, however demand in recent years has slowed. This is due to several factors:

- There is a strong correlation between the value of unmetered customers' bills and the number of meter optants each year. When unmetered bills increase, there is a corresponding increase in customers opting for a metered supply. In the last few years, increases in unmeasured bill values have been relatively small, and this has resulted in lower meter optants in these years.

- Historically we have promoted a metered supply to customers with affordability issues as a means of managing their water charges. In recent years, there has been a decrease in the number of such customers choosing to switch to a metered supply. Instead they elect to join one of our customer support schemes such as Water Direct, Water Support and Resolve, which help customers with low income or bill arrears manage their water charges.

A meter penetration forecast has been developed taking account of these factors. The assumptions behind this forecast are as follows:

- for the base year and lead-in years (AMP6) the number of DMOs is set at the average of the previous 5 years (34,054); and
- from the end of AMP6, a gradual decline in the number of DMOs to 15,000 per year by 2030/31 (AMP9), which is then a fixed rate for the rest of the planning period.

This decline reflects the decreasing number of unmeasured households both available to opt and with a financial benefit of opting.

Our plan for the next few years is to use customer segmentation data to promote metering to customers who would benefit financially from a metered supply, for example, high rateable value, low occupancy properties. We anticipate that this will allow us to achieve the forecast DMO levels in this plan.

Following publication of our draft WRMP19 we have continued to develop our approach to encouraging customers to opt to a metered supply. We are forecasting a decline in meter optants throughout the planning period as the number of unmeasured households decreases and those customers segments most likely to opt to a metered supply have already done so.

However, customers are increasingly asking if we can offer a similar arrangement to the energy sector, where suppliers are obliged to ensure customers are on the best tariff and this is an opportunity to encourage metering. We are reviewing accounts of customers who could save money from having a water meter installed. Where we estimate the customer would benefit financially, we will offer a 2-year trial of a

meter. During the trial period, we will assess whether the customers have saved money. If they haven't, we will switch them back to the unmetered rate.

As a pilot, we have identified 100,000 customers who are currently in a property with a high rateable value and a small number of occupants. Therefore, their bills are likely to be higher than they would be if they were billed according to the amount of water they consume. If the pilot is successful, we will review the accounts of approximately 650,000 unmetered customers to identify those who might be better off on a metered supply.

While this initiative will increase the number of metered customers and ensure we meet our forecast meter penetration, it may not drive a significant demand reduction as the reduced bill value from moving from a high rateable value bill to a lower metered bill may not result in a financial incentive to reduce water use.

The cost of the metering programme, including meter installation and meter reading is included in our Business Plan.

As Yorkshire is not classed as an area of water stress, compulsory metering is not an option. However, we have included additional meter optants, metering on change of occupancy and provision of smart meters as feasible options in our plan.

In addition to meter optants, all new build properties are fitted with a water meter. As a result of meter optants and new connections we forecast that 84% of all households will be metered by 2044/45.

Water efficiency savings

Our water efficiency and demand reduction strategy is set out in Section 5. This describes how water efficiency is an integral part of water resource planning, now and in the future. In our long-term strategy, which we published in March 2018, we set out our goal to take less from the environment, maximise reuse of the water we abstract and reduce water losses including leakage.

Demand management resulting from metering and water efficiency activity is central to our demand forecast for household and non-household customers.

For household customers, we will continue to promote behavioural change in water use and to provide water saving devices through free packs and home audits.

The water saving from this activity, in combination with increasing ownership of water efficient appliances, drive the downward trend in PCC presented in our household demand forecast.

We are also forecasting a continuing downward trend in total non-household water demand, driven by decreasing water use by the non-service sector. A variety of factors influence long-term non-household water demand, but economic growth and the development of water efficient technologies are considered central. The forecast of non-household demand provided by Route2 is driven by a combination of macro-economic factors and an underlying drive for efficiency.

Water efficiency is intrinsically part of the forecast household PCCs and the measured non-household consumption forecast and no additional reduction in the demand forecast due to Yorkshire Water activity has been included.

Leakage

Our baseline leakage forecast is covered in detail in Section 5. The forecast changes to total leakage impact on supply pipe leakage, which affects water delivered. The remainder of leakage comprises distribution losses.

Reported total leakage in the base year was 294.7Ml/d. For WRMP14 we calculated the sustainable economic level of leakage (SELL) at 297.1Ml/d, reducing to 287.1Ml/d by 2019/20. For the baseline planning scenario in this WRMP19 forecast leakage remains fixed at the 2019/20 value throughout the 25-year planning period.

We plan to decrease leakage significantly over the next few AMPs, leading to a total reduction of 40% by AMP9. To achieve this, we plan to start this activity within the last year of the current AMP (2019/20).

To represent this leakage activity in the WRMP19 we have incorporated all the planned activity into the final planning scenario (leaving the baseline demand forecast unchanged). This allows all additional leakage activity within the planned

programme, including costs and volume reduction detail in AMP6, to be presented in the WRMP data tables.

The information is included in column K ('For info 2019/20') within Tables 6 (Preferred (Scenario Yr)) and 8 (FP Demand), and detailed in Table 5 Feasible options.

This approach provides more clarity than alternatively representing the AMP6 leakage activity as a step change within the baseline demand forecast in 2019/20, without any supporting information within the planning tables.

It should also be noted that the leakage figures represented in our WRMP data tables do not include the effect of the recent national leakage convergence project. Whereas, our regulatory Leakage Performance Commitment target for AMP7 will be based on the convergence project.. This target will be determined once we know our actual leakage for the last year of AMP6 and, as a result of convergence, it will produce a target that will be different to the WRMP19 leakage target. There are two reasons why convergence has created different targets. Firstly, calculated leakage for the base year for this WRMP (2015/16) pre-dates the leakage convergence project; therefore, the leakage figures in WRMP tables must also represent pre-convergence in order to be consistent with the base year. Secondly, the full impact of convergence is not yet known, and convergence reporting is being shadow reported until 2020. For this reason, we have used a percentage basis for the leakage Performance Commitment for our 2020-25 regulatory business plan to avoid the uncertainty created by the change in reporting. Representing the leakage reduction as a percentage is in line with Ofwat's PR19 Final Methodology, and corresponds with the way leakage improvements are considered in the totex cost allowances.

Properties and population

The amount of water delivered to each property category depends on the number of properties in that category and any associated population.

Property and population data for the base year was extracted from the billing file and is used as the basis for the forecasts in future years.

Households

Household properties

The forecast for total household properties and their associated population was produced by Edge Analytics Ltd, *Population, Household & Property Forecasts* (Edge Analytics, 2016). To meet our requirements, two population forecasts were prepared. The first is a housing-led scenario, using housing growth evidence from Local Plans, known as a plan-based forecast. The second is based on the latest 2014-based Sub-National Population Projections (SNPP) from the ONS, known as a trend-based forecast.

The *Water Resources Planning Guidelines* (Environment Agency and National Resources Wales, 2017), emphasizes the importance of using housing growth evidence from Local Plans. Therefore, we have selected to use the plan-based property and population forecast from Edge Analytics for the WRMP19.

Edge Analytics collected Local Plan housing growth evidence from all local authorities that are either wholly or partially within the Yorkshire Water operational boundary. At the time, each of the 25 local authorities and 3 National Park authorities was at a different stage of Local Plan development. Some plans were adopted, whereas others were under development or open for consultation.

Where available, the annual allocation of the overall housing target was taken from the information provided by each local authority. When not available, the overall housing target was distributed equally over the Local Plan period, with adjustments made to account for historic completions if this was available.

These annual housing growth trajectories formed the basis of the plan-based household forecast used in the demand forecast.

Under the trend-based forecast, which is based on historic trends in births, deaths and migration, the number of household properties and population forecast are significantly less than the plan-based forecast. The impact of this potentially lower number of households and population on future demand for water has been assessed and included in our allowance for uncertainty, as described in Section 7 of this plan.

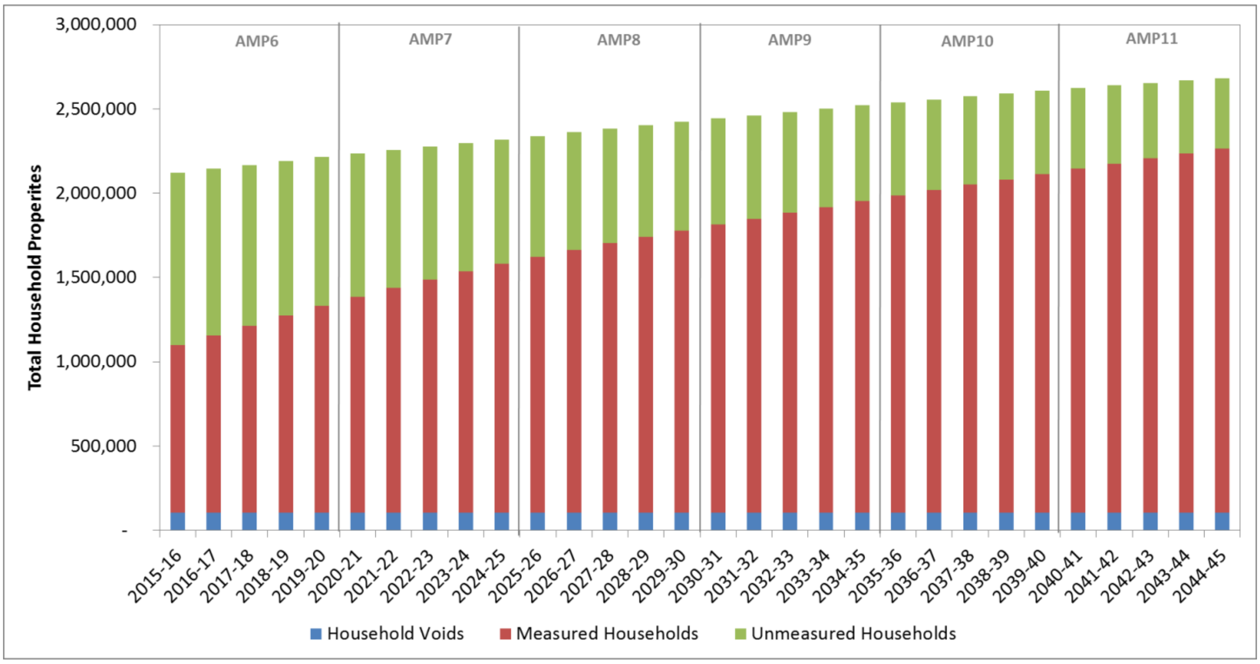
The plan-based forecasts of household properties and population were rebased to align with our billing file in the base year.

The total household properties were divided between the measured and unmeasured household categories using our DMO forecast and the new builds forecast taken from the Edge Analytics forecast, as follows:

- Measured households = measured households in previous year + new builds + DMOs
- Unmeasured households = unmeasured households in previous year - DMOs

The household property forecast is presented in Figure 4.4.

Figure 4.4 Household property forecast



Household population

The total household population (shown in Table 4.6) is split between the measured and unmeasured household categories using occupancy rates. Edge Analytics also provided an occupancy rate forecast. However, these were tied to their property and population forecasts which we have amended, as detailed above. Our amended

occupancy rates are forecast forward from the revised base year occupancy rates obtained from CACI (discussed in Section 4.3.1) and assumed DMO occupancy.

Table 4.6 Summary of household population by AMP period

Household Population		2015/16 (Base Year)	2019/20 (end AMP6)	2024/25 (end AMP7)	2029/30 (end AMP8)	2034/35 (end AMP9)	2039/40 (end AMP10)	2044/45 (end AMP11)
Measured Households	Grid SWZ	2,239,798	2,642,751	3,131,983	3,519,025	3,842,911	4,163,407	4,482,381
	East SWZ	11,110	12,981	15,226	16,849	18,159	19,529	20,885
Unmeasured Households	Grid SWZ	2,650,670	2,436,017	2,145,831	1,942,381	1,782,609	1,607,039	1,417,596
	East SWZ	14,620	13,248	11,450	10,166	9,202	8,205	7,144
Total		**4,916,198**	**5,104,997**	**5,304,491**	**5,488,422**	**5,652,880**	**5,798,181**	**5,928,007**

The measured household occupancy rate shows a gradual decline over the plan period and the unmeasured household occupancy rate shows a gradual increase. This assumes that the DMO properties will be those households within the unmeasured household category with lower occupancy rates, for whom switching to a metered supply will present a cost saving.

The clandestine and hidden population has been fixed at the base year number, which was provided in *Clandestine and Hidden Populations* (Edge Analytics, 2017). This population is split between the measured and unmeasured households as described in Section 4.3.1.

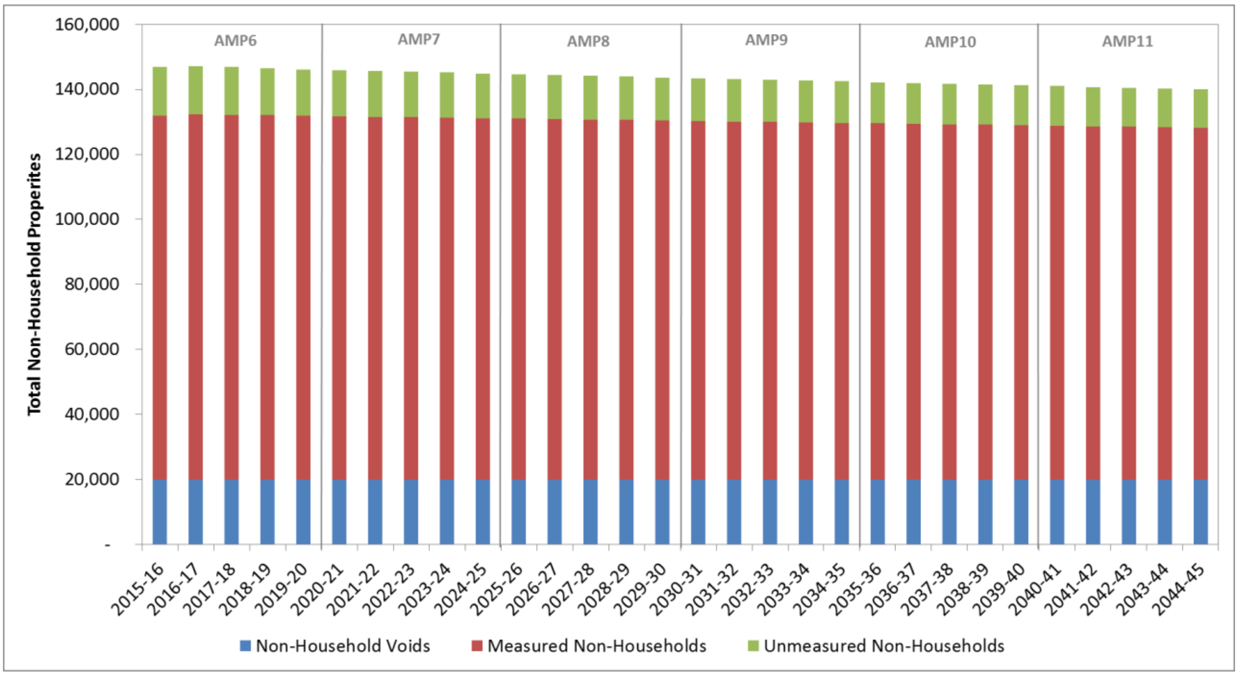
Non-households

Measured non-household properties

The measured non-household properties are forecast based on estimated new commercial connections and demolitions/ change of use properties, which are inferred from analysis of historical trends. The average new connections and recorded demolitions in the five years between 2010/11 and 2014/15 were used for

the forecast. The total measured non-households were then split between the water resource zones using the base year percentage split. The non-household property forecast is presented in Figure 4.5.

Figure 4.5 Non-Household property forecast



Measured non-household population

The measured non-household population is the communal population, which was forecast in *Population, Household & Property Forecasts* (Edge Analytics, 2017) at water resource zone level. For the Grid SWZ, the population of a military garrison in North Yorkshire was removed from the communal population as it has its own water supply. The communal population is summarised in Table 4.7 below.

Table 4.7 Summary of communal population by AMP period

Communal Population	2015/16 (Base Year)	2019/20 (end AMP6)	2024/25 (end AMP7)	2029/30 (end AMP8)	2034/35 (end AMP9)	2039/40 (end AMP10)	2044/45 (end AMP11)
Grid SWZ	77,076	79,022	84,483	90,297	97,195	102,198	106,222
East SWZ	538	547	571	609	650	671	676
Total	**77,613**	**79,569**	**85,054**	**90,906**	**97,845**	**102,869**	**106,898**

Unmeasured non-household properties

The unmeasured non-household property forecast is based on an observed declining trend. This data showed an average decrease of approximately 200 properties per year in AMP5. We considered that applying this annual decrease throughout the whole plan period would result in too many properties being lost by 2044/45. Therefore, the most appropriate forecast was assumed to be annual decreases of 200 properties for AMP6, and 100 properties from AMP7 onwards. The total unmeasured non-households were then split between the water resource zones using the AMP5 average percentage split.

Mixed-use properties, which are a sub-division of the unmeasured non-households, were calculated as a percentage of the total unmeasured non-households based on historic data.

Unmeasured non-household population

The unmeasured non-household population (Table 4.8) is calculated as the mixed-use properties multiplied by the unmeasured household occupancy rate.

Table 4.8 Summary of unmeasured non-household population by AMP period

Unmeasured Non-Household Population	2015/16 (Base Year)	2019/20 (end AMP6)	2024/25 (end AMP7)	2029/30 (end AMP8)	2034/35 (end AMP9)	2039/40 (end AMP10)	2044/45 (end AMP11)
Grid SWZ	3,999	4,017	4,086	4,090	4,088	4,079	4,070
East SWZ	368	362	360	352	347	341	334
Total	**4,367**	**4,378**	**4,446**	**4,442**	**4,435**	**4,420**	**4,405**

Void properties

It is assumed that the number of void properties (household and non-household) is maintained at the base year number of 123,237 for the plan period. These properties have no population associated with them. The forecast household and non-household voids are presented in Figures 4.4 and 4.5 respectively.

Total population

The total population forecast for the plan period is summarised in Figure 4.6 and Table 4.9.

Figure 4.6 Total population forecast

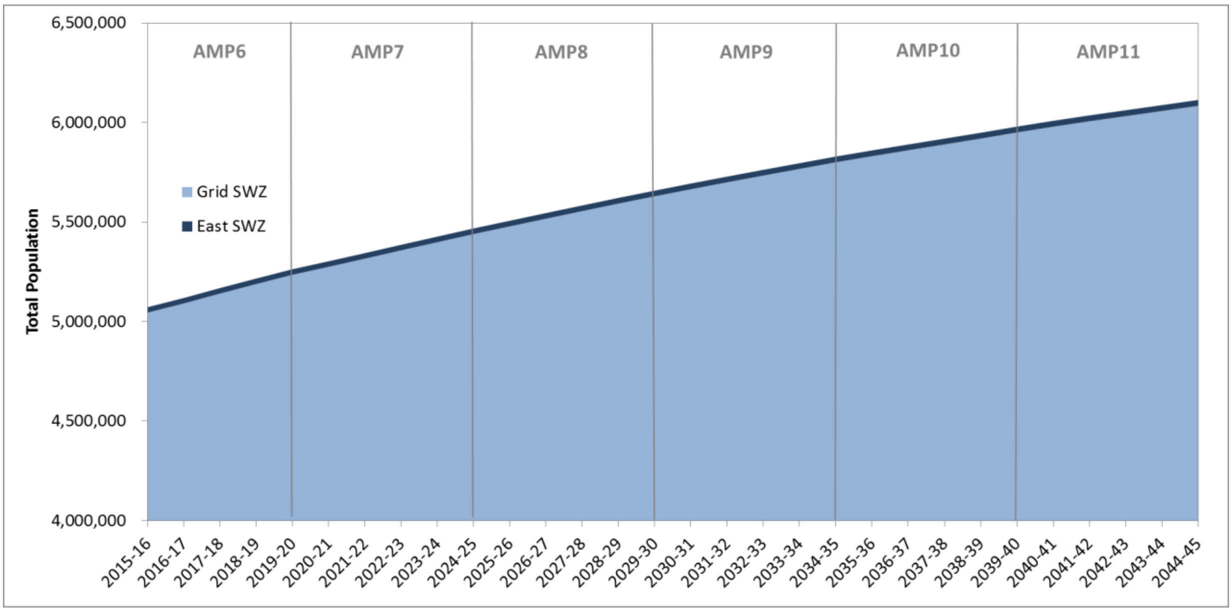


Table 4.9 Summary of total population forecast by AMP period

Population Forecast	2015/16 (Base Year)	2019/20 (end AMP6)	2024/25 (end AMP7)	2029/30 (end AMP8)	2034/35 (end AMP9)	2039/40 (end AMP10)	2044/45 (end AMP11)
Grid SWZ	5,045,667	5,235,931	5,440,507	5,629,917	5,800,926	5,950,848	6,084,393
East SWZ	27,199	27,701	28,170	28,539	28,920	29,309	29,602
Total	**5,072,865**	**5,263,631**	**5,468,677**	**5,658,456**	**5,829,847**	**5,980,157**	**6,113,995**

Consumption

Consumption is the water used by a property, which includes the volume used by the property and meter under registration but excludes supply pipe leakage.

Household consumption

The forecast volume of water used by household properties is calculated from PCC and population.

We commissioned water consultants Artesia Consulting Ltd to develop a household consumption model, which provides PCC for measured and unmeasured households throughout the plan period - *Yorkshire Water WRMP19 Household Consumption Forecast,* (Artesia Consulting, 2017). Following guidance provided in the *WRMP19 Methods - Household Consumption Forecasting* (UKWIR, 2015), Artesia Consulting used multivariate linear regression modelling of validated historic demand data to create consumption models for our two water resource zones.

The multivariate linear regression models integrate drivers of future household demand, such as occupancy, property type, socio-demographics and meter penetration. The models can be used to test sensitivities of different parameters, such as meter uptake and maximum meter penetration.

Artesia Consulting validated their models using four different approaches:

- Firstly, the model was constructed using standard statistical methods from which uncertainty can be quantified.
- Secondly, the model was validated temporally, both within the trainer set and by applying the model to historic data and forecasting forwards to the current year and comparing with reported figures.
- Thirdly, the model was validated spatially at household level.
- Finally, the model coefficients were shown to be similar between models derived from different Yorkshire Water databases.

In preparation of our household demand model we have chosen to segment our customers by meter status, property type, occupancy rate and socio-demographic profile, due to the availability of comprehensive data for these segments. We have not segmented by behavioural typology as we currently have insufficient customer information of this type available to allow us to do this. We therefore have not used the methodology described in *Customer behaviour and water use: A good practice*

manual and roadmap for household consumption forecasting (UKWIR, 2012) in developing our demand model.

Artesia Consulting combined observed micro-component trends with calculated endpoint scenarios to derive possible trends in water use. For example, the water efficiency of washing machines and dishwashers is improving, whereas frequency and duration of showering may be increasing. From this they have derived potential scenarios of water use based on upper and lower trends.

- The **sustainable development** scenario assumes the current regulatory-driven efficiency in technology will continue beyond 2045, resulting in water use reductions that are currently not economically viable.
- Conversely the **market forces** scenario assumes the projected trend in micro-components does not continue beyond 2022. This would be driven by the decoupling of UK building standards from current standards.
- The two calculated trends are considered by Artesia Consulting to be the extremes that represent the upper and lower bounds of the forecast. The observed trend was averaged with the sustainable development and market forces trend to give a **central** trend.

The central trend has been used as the forecasting trend within the measured and unmeasured household demand forecast. The central model outputs provide measured and unmeasured household PCC and per household consumption (PHC) forecasts for the planning period. We add uplifts for climate change and dry year to the household PCC values.

The PCC forecasts derived from the sustainable development and market forces scenarios have been included in our modelling of uncertainty for this plan (Section 7).

Climate change

Following guidance from the Environment Agency, we have used the climate change scenarios presented in the *Impact of Climate Change on Demand* (UKWIR, 2012) to determine the potential impact of climate change on customer demand.

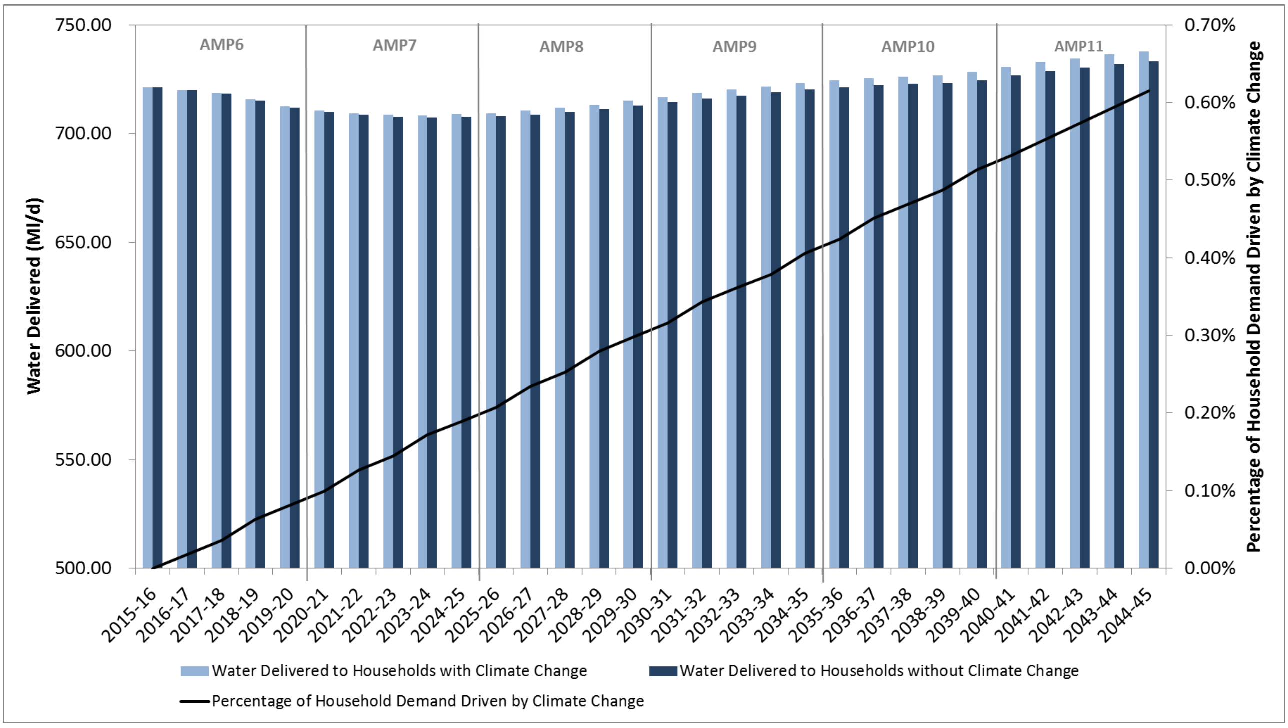
We have assumed that the Severn Trent scenarios are more appropriate to Yorkshire Water than the Thames Water scenarios, due to geographical and climatic similarities. We selected the Household Annual Average for the Humber North region as the most appropriate climate change scenario for the Yorkshire Water supply area. We also selected the mid-range P50 percentile scenario within the Humber North region as there is no evidence to justify use of the higher or lower ranges.

The Defra commissioned report *Climate Change and Demand for Water* (CCDeW, 2003) states that the major impact of climate change in north east England is likely to be on garden use and personal washing. Climate change has therefore been added on to these two micro-components of household demand.

The result is a forecast growth in household consumption due to climate change of 0 to 0.61% over the planning period.

Figure 4.7 demonstrates the forecast increase in household demand due to climate change. Climate change has not been included in the demand forecast for non-household properties. This is because there is no evidence of an impact on industrial demand. Equally, there is little potable water supplied for irrigation purposes in Yorkshire, and therefore, we are assuming no impact on agricultural demand in our region.

Figure 4.7 Impact of climate change on household demand



Dry year effect

The reported demand forecast is for a dry year annual average scenario, in accordance with the *Water Resources Planning Guideline* (Environment Agency and Natural Resources Wales, 2017). The methodology used to estimate a dry year effect is described in Section 4.3.1. This value (1.913%) is applied as a percentage uplift to average PCC each year.

The PCC values from the water resource planning tables are presented in Table 4.10. It is important to note that these include meter under registration and MLE adjustments as they are calculated in the water resources planning tables by dividing household consumption by household population.

The forecast weighted average PCC values for all household customers in the Yorkshire Water region are also provided in Table 4.10.

Table 4.10 Summary of dry year annual average PCC forecast by AMP period

DYAA PCC (l/h/d)		2015/16 (Base Year)	2019/20 (end AMP6)	2020/21	2021/22	2022/23	2023/24	2024/25 (end AMP7)	2029/30 (end AMP8)	2034/35 (end AMP9)	2039/40 (end AMP10)	2044/45 (end AMP11)
Measured Households	Grid SWZ	101.8	103.2	103.4	103.5	103.6	103.7	103.8	104.5	105.1	105.0	104.0
	East SWZ	101.1	102.6	102.7	102.9	103.0	103.1	103.2	104.0	104.6	104.6	103.6
Unmeasured Households	Grid SWZ	155.0	147.8	146.3	145.0	143.8	142.8	141.8	137.9	134.7	131.7	135.6
	East SWZ	155.2	147.9	146.4	145.1	144.0	143.0	142.0	138.0	134.8	131.9	135.7
Weighted Average		130.6	124.6	123.3	122.2	121.1	120.1	119.3	116.5	114.5	112.6	111.7

Currently we have 50% metered households, and this number is increasing each year due to meter optants and new development. Unmeasured household PCC is forecast to decline due to increasing water efficient behaviour and ownership of water efficient appliances, such as dishwashers and washing machines.

The forecast is for a slightly increasing measured household PCC driven by:

- those households that use more water gradually switching to a metered supply; and

- increasing numbers of low occupancy households, which have an associated higher PCC (proportionately higher water use per person due to use of appliances such as washing machines/dishwashers).

The average household PCC is forecast to decline due to an increasing proportion of measured households (with associated lower PCC), increasing water efficient behaviour and use of water efficient appliances.

To comply with the *Water Resources Planning Guideline* (Environment Agency and Natural Resources Wales, 2017), Artesia Consulting produced a micro-component forecast which was developed from property survey data.

This micro-component model allows reporting of PCC in the following categories, as required for the water resources planning tables:

- toilet use;
- personal washing;
- clothes washing;
- dish washing;
- garden watering; and
- other use (includes plumbing losses, swimming pools, and drinking water).

Figures 4.8 and 4.9 present the percentage breakdown of PCC into these micro-components. These present the splits for the base year and the final year of the plan period. Climate change, which affects personal washing and garden watering, alters the percentage splits year on year.

Figure 4.8 Percentage breakdown of measured household PCC

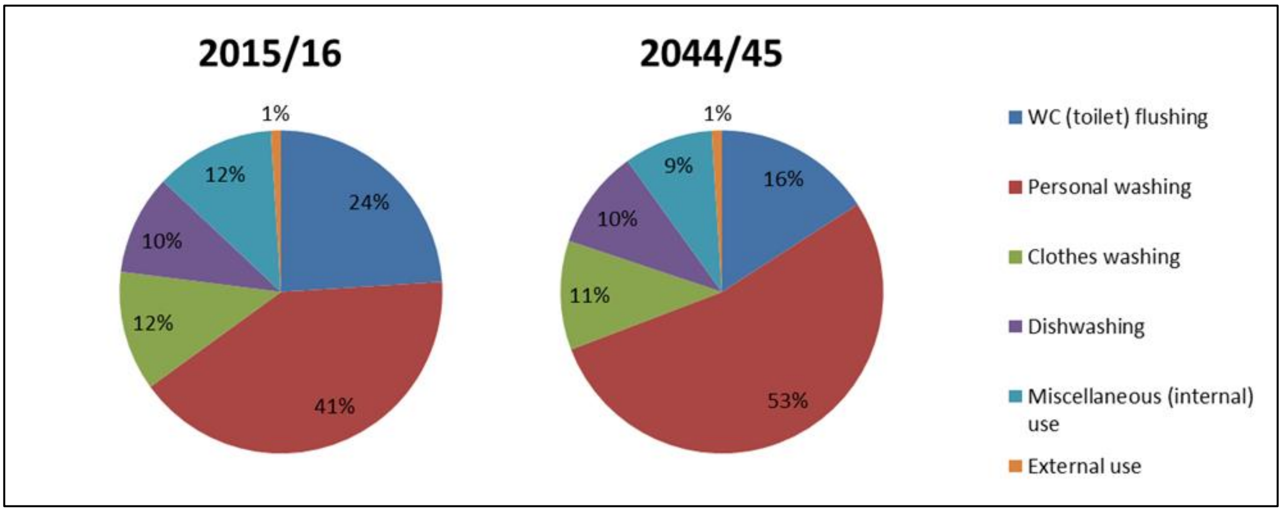
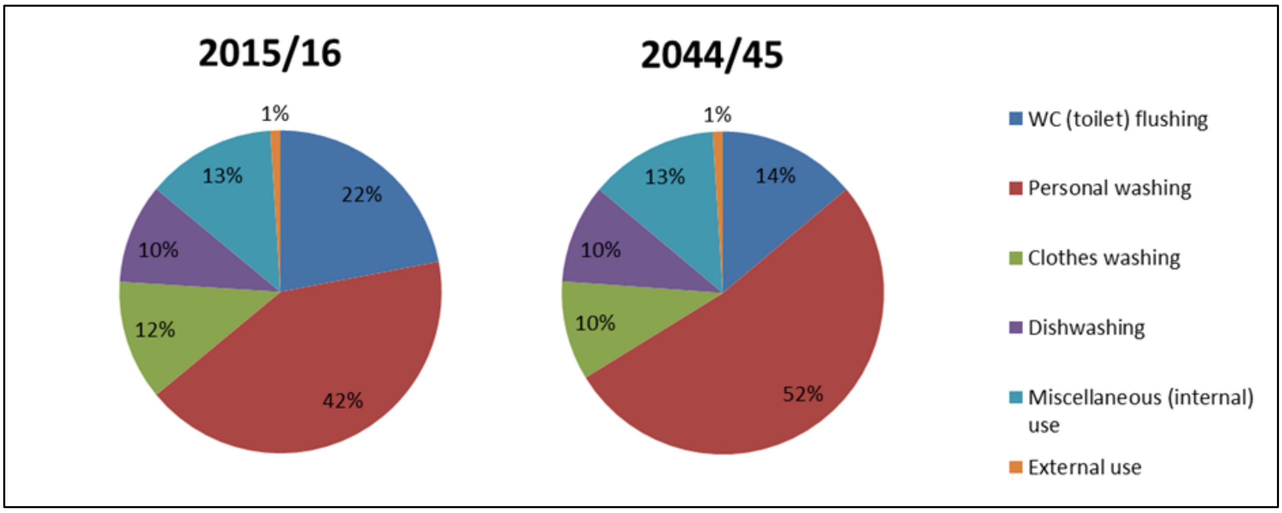


Figure 4.9 Percentage breakdown of unmeasured household PCC



Clandestine and hidden consumption

The clandestine and hidden consumption is calculated in the same way as for the base year. It is assumed that the measured household clandestine and hidden consumption is captured by water meters and therefore no additional consumption is included. For the unmeasured household clandestine and hidden population, consumption is calculated using the unmeasured household PCC.

Measured non-household consumption

There have been several changes associated with the measured non-household sector in recent years. The opening of the retail market has seen several changes in

customer classification. In developing our measured non-household demand forecast we have used a dataset that reflects the eligibility criteria regarding the measured non-household retail market in England.

As part of our preparation for market opening, we reviewed our measured non-household portfolio to ensure that all eligible customers are in the market. The demand dataset uses to develop our forecast demand reflects the current eligibility criteria in historic measured volumes.

Measured non-household demand within Yorkshire has been broadly declining over the last twenty years. In developing our demand forecast we have looked separately at the two categories of measured non-household customers, non-service and service sectors. A steady increase in total demand from the service sectors has been observed, with a steady decline in total demand from the non-service sector.

We have collaborated with Route2 Sustainability Ltd (Route2) to develop multiple regression analysis models to forecast long-term water demand. Separate models were developed for non-service and service sectors, to reflect the differing demand profiles of these broad customer groups over time. Historic demand for the period 1997 to 2016 was used to develop the models, providing demand forecasts for the period 2017 to 2060.

Multiple regression analysis uses known values known as ‘independent’ variables to predict an unknown value, or ‘dependant’ variable. Water demand in the modelling is the dependent variable, with three independent variables used to determine future water demand.

A variety of factors can influence long-term service and non-service sector water demand. We considered 120 independent macro-economic variables to determine the top three independent variables that best determine future water demand for the two sectors. These are presented in Table 4.11 below.

Table 4.11 Measured non-household forecast models

Forecast Model	Model 1 – Service sector	Model 2 – Non-service sector
Dependent Variable	Yorkshire Water service sector water demand (Ml/d)	Yorkshire Water non-service sector water demand (Ml/d)
Independent Variables/ Predictors	GDP / Capita (GBP) Labour Productivity in Service Sectors (Hours / Week) Total Energy Consumption in Service Sectors	Yorkshire Non-Service Sector Employment (No.) UK Multi Factor Productivity (Hours / Week) Petrol Consumption in Non-Service Sectors

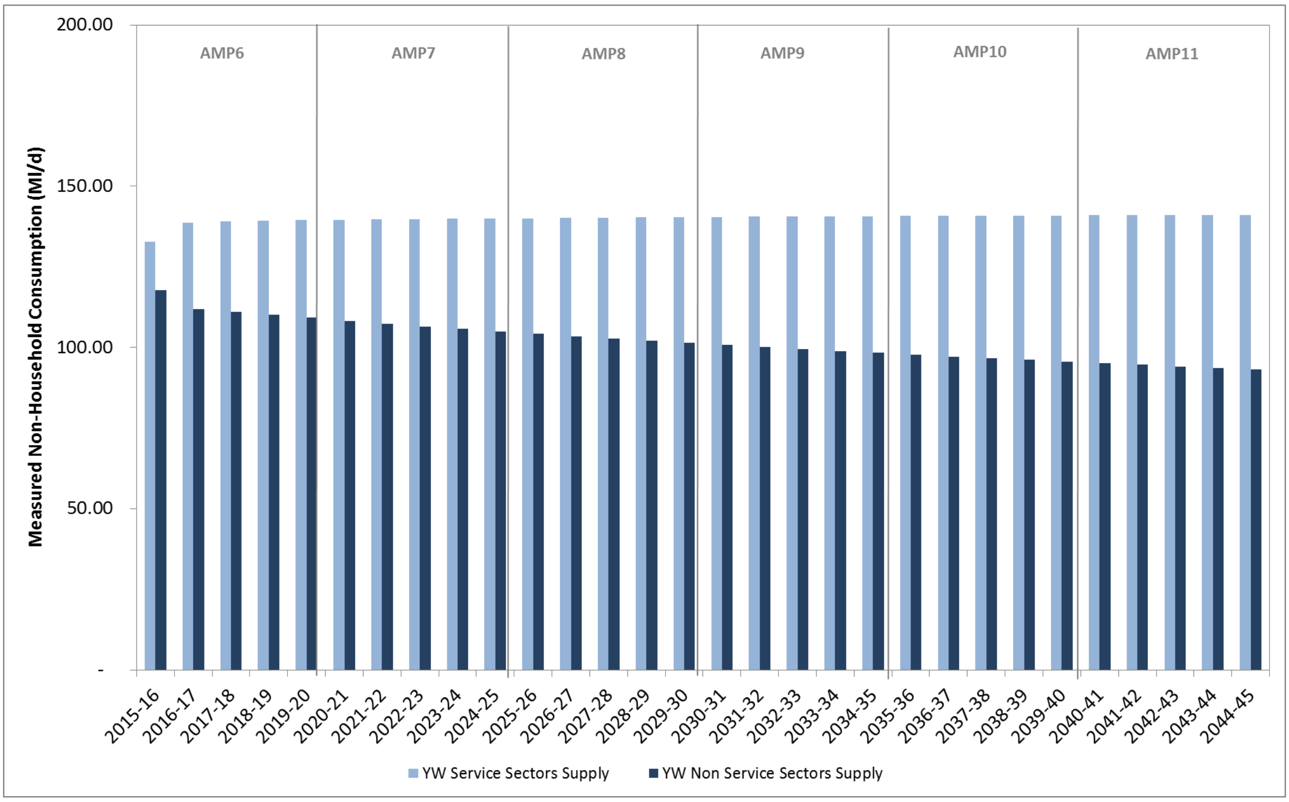
In the development of forecasts there is likely to be a level of uncertainty or inaccuracy in predictive modelling. To deal with this uncertainty Route2 have developed four scenarios and assessed the impact of these on demand from non-household customers.

The four scenarios of consumption and governance; business as usual, heavy government, resilience and consumer power, were based on the *Water for people and the environment* (Environment Agency, 2009) report. Forecast demand under these scenarios has been included in uncertainty modelling for this plan.

Figure 4.10 10 shows the measured non-household consumption used in the demand forecast split into service and non-service sectors. The scenario selected was the Route2 baseline scenario, which we rebased to our annual water balance data for the base year.

A variety of factors influences non-service and service long-term water demands. Key factors are economic growth and technological development, specifically in water use and water efficiency technologies. We have not made a specific adjustment to this forecast for water efficiency as we consider these impacts are included within the forecast.

Figure 4.10 Measured non-household consumption



In February 2018 we undertook qualitative research to understand the challenges faced by, and services required by non-household retailers in our region. As part of this research retailers were asked about planned water efficiency activity and known areas of growth for inclusion in WRMP19 forecasts.

The research found that only efficiency-specialist retailers had any plans for water efficiency, and these were general plans rather than targeted specifically at customers in the Yorkshire Water supply area. Current water efficiency resources are focussed in the South East and South West regions, where there is more demand.

Retailers were unable to provide any detail of known efficiency or growth and were unable to forecast any short or long-term changes in demand.

We have therefore not included any amendments to our non-household demand forecast as a result of this engagement.

We have also considered the potential impact of new customers swapping from a non-public water supply, such as salad growers requiring a potable water supply. This requirement has historically been minimal in Yorkshire and it is considered unlikely to become a significant driver of demand in the future.

Unmeasured non-household consumption

The estimated volume of water used by unmeasured non-households has been revised in line with best practice provided in *Consistency of Reporting Performance Measures* (UKWIR, 2017). The report recognises that this component is normally a small proportion of total non-household demand and suggests that an estimate of consumption is derived from a study of the consumption of Standard Industry Classification (SIC) equivalent measured non-households of similar SIC categories.

However, this would lead to a significant over estimation in unmeasured non-household volume, as it is incorrect to assume that unmeasured non-household and measured non-household properties within a SIC category have similar water use. Unmeasured non-household properties have very low or irregular water use compared to measured non-households, and because of this fitting a meter at these properties is not cost beneficial.

As these unmeasured non-household properties are low consumers, the methodology was revised to limit comparison with metered non-households with similarly low water use. For this exercise measured properties with water use of less than 0.349m^3/day were considered, which was the current average unmeasured household consumption.

This gives a total unmeasured non-household consumption of 2.12Ml/d, and an estimated volume per property of 125l/prop/day.

Meter under registration

Meter under registration is assumed to remain at the base year rate. The meter under registration percentages for measured households, unmeasured households and measured non-households are given in Section 4.3.1. Meter under registration does not apply to unmeasured non-households.

Supply pipe leakage

The forecast total volume of supply pipe leakage is directly linked to total leakage. Total supply pipe leakage has been estimated to be 31.17% of leakage in DMAs. This was calculated from an assessment of properties on our Domestic Consumption Monitor. The supply pipe leakage volume is allocated to all properties based on estimated leakage rates for different property types and meter locations.

We have three different supply pipe leakage rates for properties:

- standard supply pipe leakage rate for unmeasured and internally metered properties;
- measured households with meters located external to the property (half standard rate); and
- measured non-household (one-quarter standard rate).

As the total number of properties in each category varies each year, the supply pipe leakage rates vary subtly each year also.

4.4.2 Water taken unbilled

We estimate the volume of water taken unbilled annually as part of our water balance calculations. The total estimated volume remains constant at around 30Ml/d (2% of distribution input) each year. Therefore, the amount of water taken unbilled is assumed to be fixed at the base year volume (31.92Ml/d) for the remainder of the plan period.

4.4.3 Distribution losses

As discussed in Section 4.3.2, distribution losses comprise leakage from service reservoirs and trunk mains, plus the losses in DMAs which are not supply pipe leakage.

The leakage from service reservoirs and trunk mains for the base year was estimated as 44.65Ml/d. This volume has been applied throughout the plan period.

Leakage in DMAs, excluding supply pipe leakage, is also fixed throughout the plan period from 2019/20 at 166.83Ml/d.

4.4.4 Distribution system operational use

The volume of water used for distribution system operations (for example, mains flushing, service reservoir cleaning and water quality testing) is assumed to be fixed during the plan period at the base year volume (1.80Ml/d).

4.5 Forecast demand to 2044/45

4.5.1 Water delivered

Household water delivered

The forecast regional water delivered to household properties over the planning period is presented in Figure 4.11 and Table 4.12. Note that this includes the dry year uplift and climate change impact on demand.

The measured household water delivered is forecast to increase from 256.04Ml/d in the base year to 521.02Ml/d by 2044/45. This increase is a combination of increased property numbers (new build households and DMOs) and a small uplift due to climate change.

The unmeasured household water delivered is forecast to decrease over the planning period, from 465.12Ml/d in the base year to 216.80Ml/d in 2044/45. This is due to a continuing trend of households switching to a metered supply.

Figure 4.11 Water delivered to households

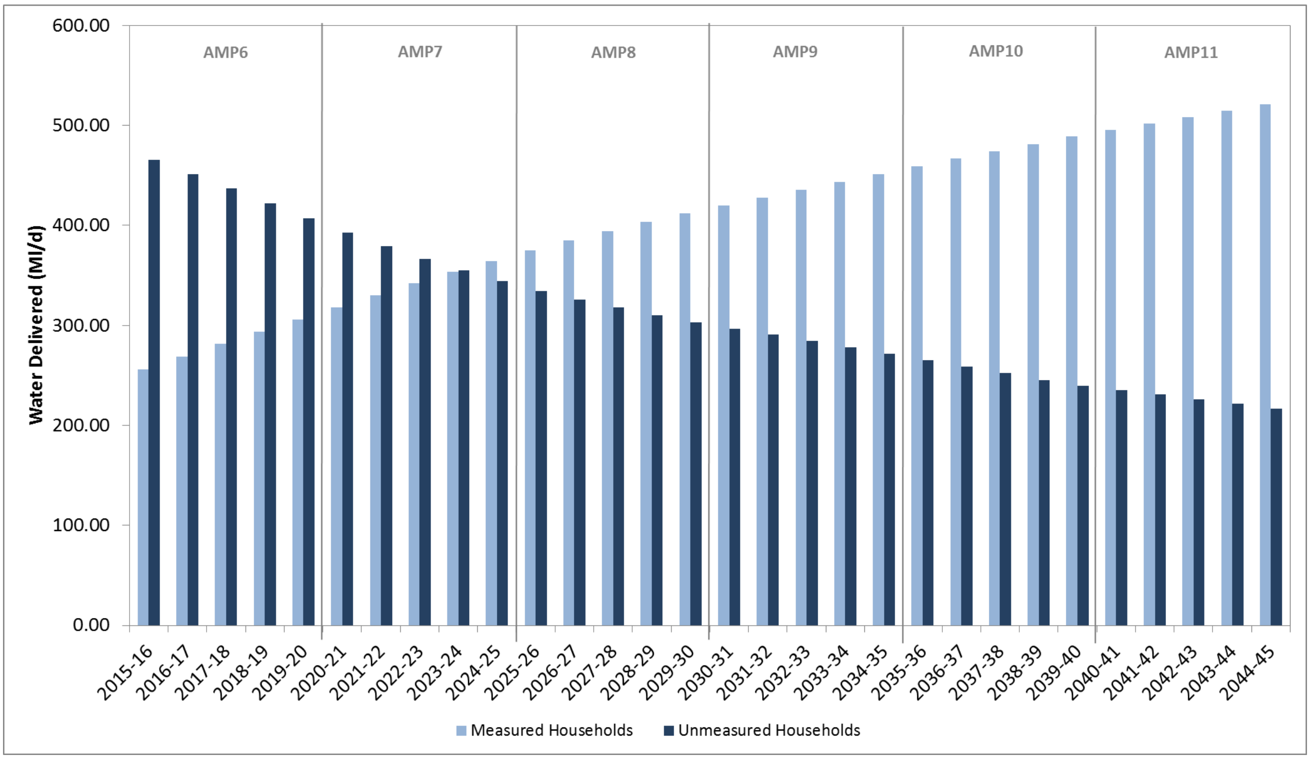


Table 4.12 Water delivered to households

Dry Year Forecast Water Delivered (Ml/d)	Measured Households		Unmeasured Households	
	2015/16	2044/45	2015/16	2044/45
Grid SWZ	254.76	518.58	462.51	215.67
East SWZ	1.28	2.44	2.62	1.13
Total	**256.04**	**521.02**	**465.12**	**216.80**

Measured non-household water delivered

The regional measured non-household water delivered (Figure 4.12 and Table 4.13) is forecast to decrease from 269.33Ml/d in the base year to 251.72Ml/d in 2044/45. This is primarily due to the impact of the economy and increased water efficiency, particularly within the non-service sector, as described in Section 4.4.1.

Figure 4.12 Water delivered to measured non-households

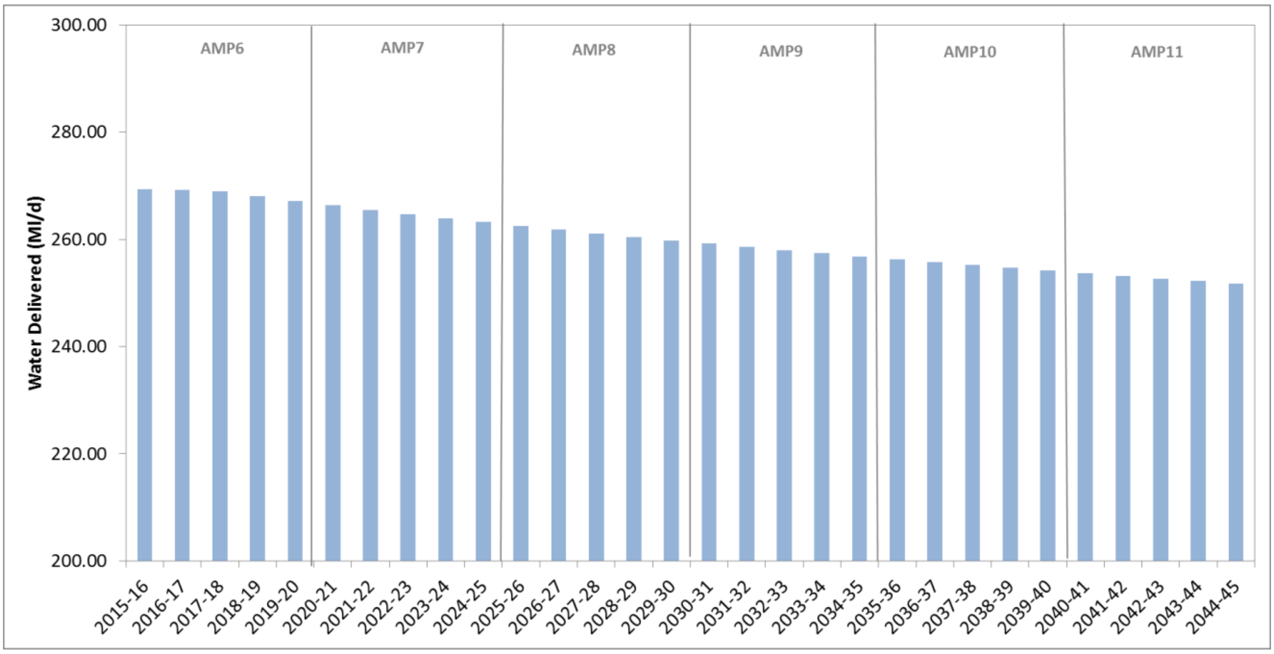


Table 4.13 Water delivered to measured non-households

Measured Non-household Water Delivered (Ml/d)	2015/16	2044/45
Grid SWZ	267.83	250.31
East SWZ	1.50	1.41
Total	**269.33**	**251.72**

Unmeasured non-household water delivered

The unmeasured non-household water delivered (Figure 4.13 and Table 4.14) decreases during the plan period, from 2.74Ml/d in the base year to 2.13Ml/d by 2044/45. This is due to the forecast decline in unmeasured non-household property numbers over the planning period.

Figure 4.13 Water delivered to unmeasured non-households

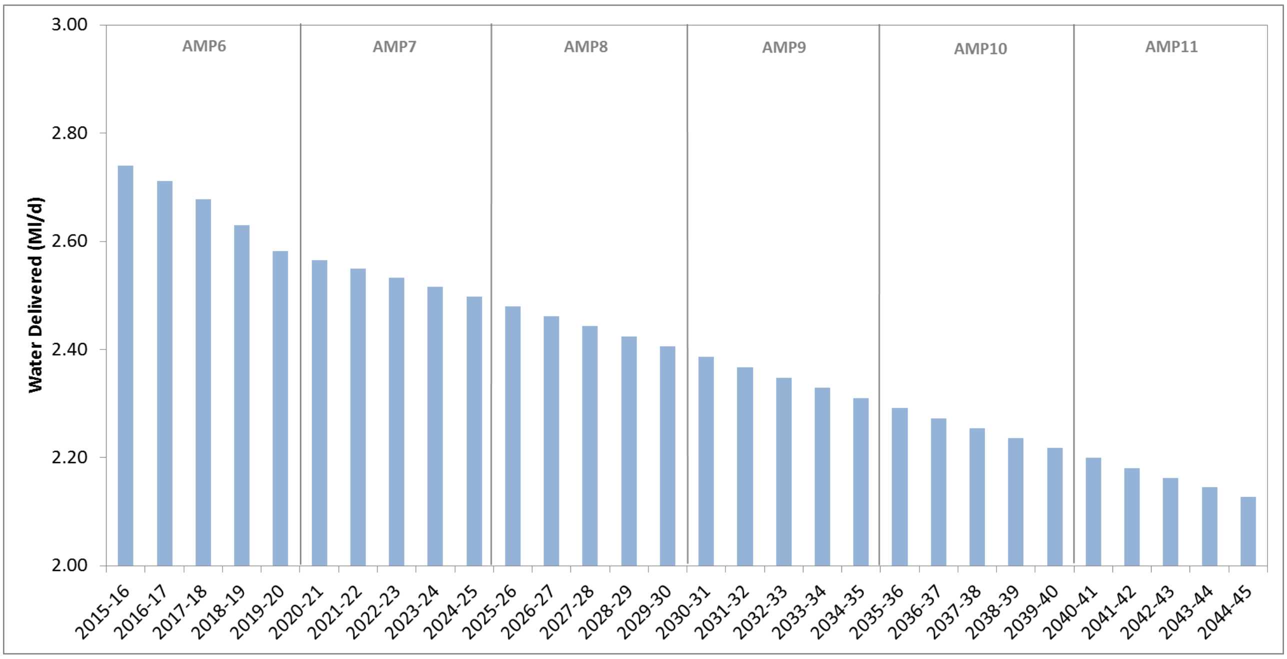


Table 4.14 Water delivered to unmeasured non-households

Unmeasured Non-household Water Delivered (Ml/d)	2015/16	2044/45
Grid SWZ	2.70	2.10
East SWZ	0.04	0.03
Total	**2.74**	**2.13**

Total water delivered

The total water delivered is the sum of water delivered to all properties (including voids) and unbilled water.

The water delivered to void properties (households and non-households) decreases over the planning period, from 5.57Ml/d in the base year to 5.44Ml/d in 2044/45. This is based on supply pipe leakage volumes and total property numbers.

Water taken unbilled is fixed during the plan period.

The total water delivered is forecast to increase slightly over the planning period from 1,030.72Ml/d in the base year to 1,029.03Ml/d in 2044/45, as presented in Figure 4.14 and Table 4.15.

Figure 4.14 Total water delivered

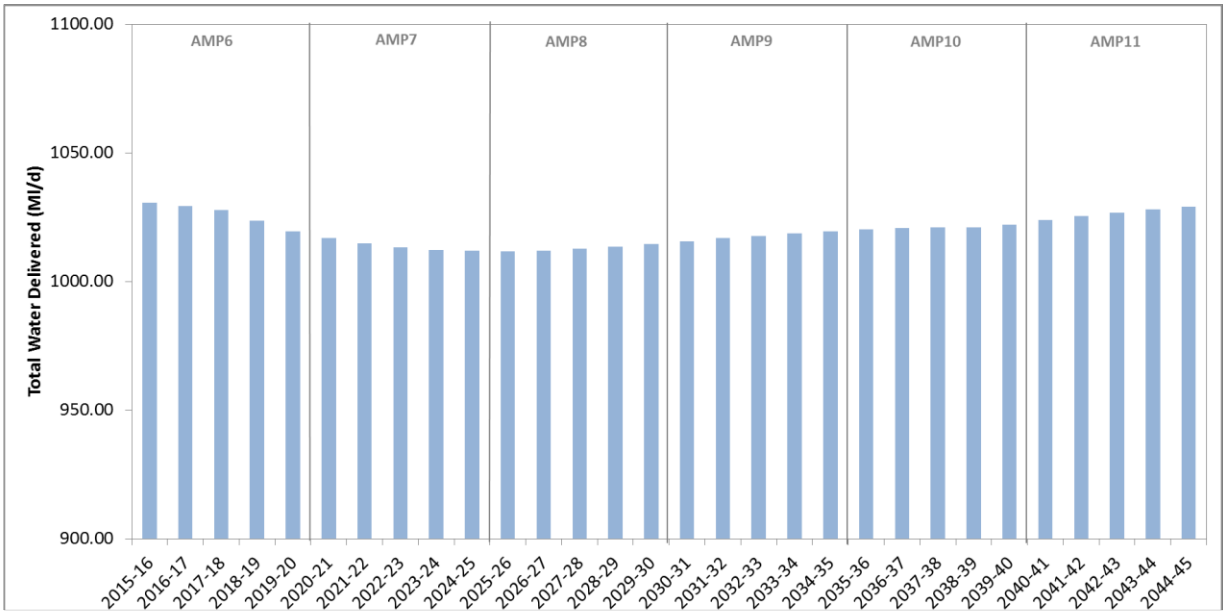


Table 4.15 Total water delivered

Total Water Delivered (Ml/d)	2015/16	2044/45
Grid SWZ	1,025.07	1,023.80
East SWZ	5.65	5.23
Total	1,030.72	1,029.03

4.5.2 Distribution Input

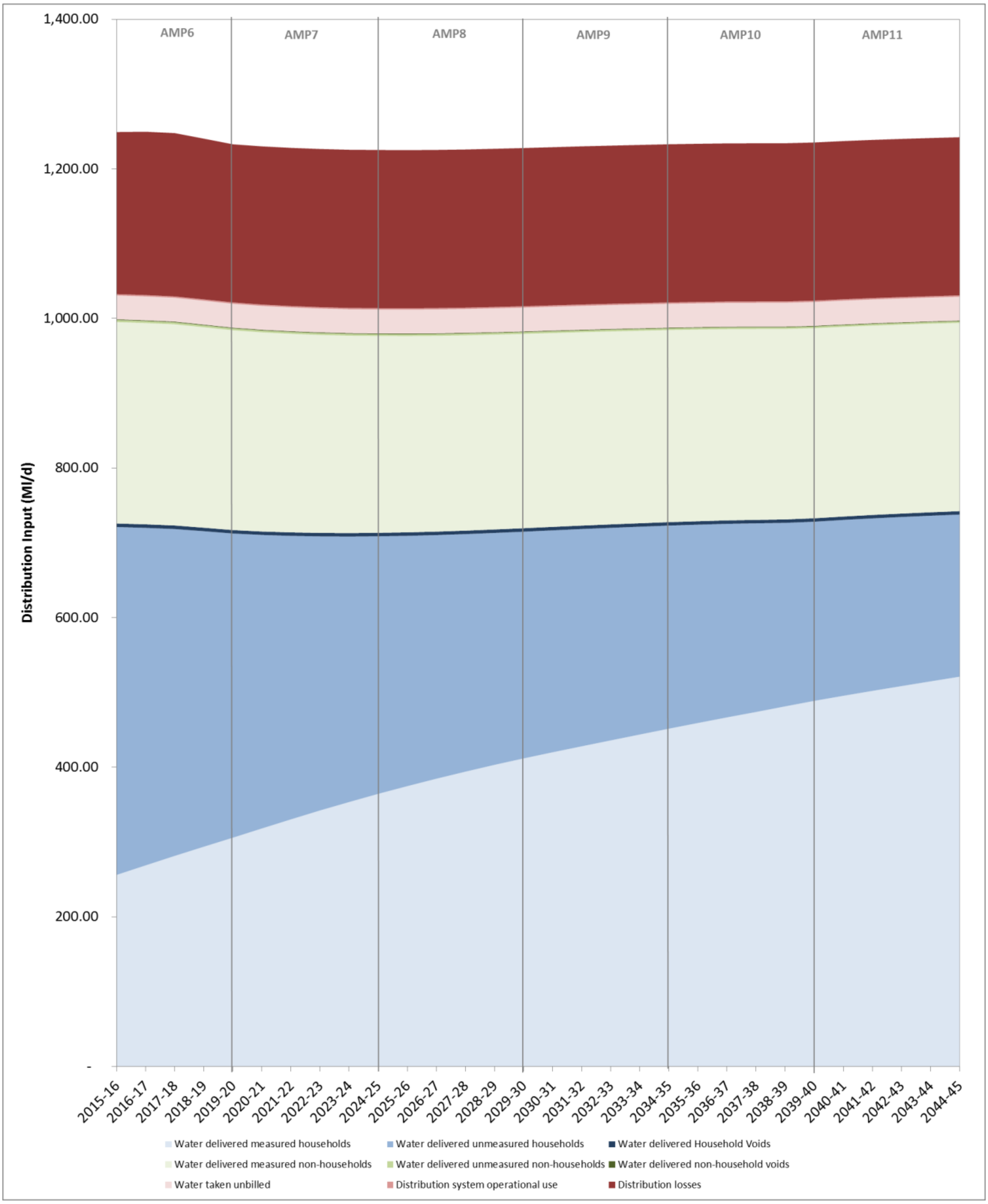
Forecast total demand (distribution input) decreases slightly over the planning period from 1,249.23Ml/d in the base year to 2,242.31Ml/d in 2044/45. A summary of distribution input is presented in Table 4.16 below.

Figure 4.15 shows the build-up of the individual components of demand to produce distribution input.

Table 4.16 Distribution input

Distribution Input	2015/16 (Base Year)	2019/20 (end AMP6)	2024/25 (end AMP7)	2029/30 (end AMP8)	2034/35 (end AMP9)	2039/40 (end AMP10)	2044/45 (end AMP11)
Grid SWZ	1,242.85	1,226.65	1,219.11	1,221.80	1,226.92	1,229.35	1,236.37
East SWZ	6.38	6.23	6.10	6.03	5.99	5.95	5.94
Total	**1,249.23**	**1,232.88**	**1,225.21**	**1,227.82**	**1,232.90**	**1,235.29**	**1,242.31**

Figure 4.15 Total distribution input



4.6 Extended forecast to 2059/60

We have extended the demand forecast 15 years beyond the 25-year statutory minimum planning period to 2059/60.

We have a lack of certainty this far into the future, therefore the methodology that we have followed to forecast the 15-year extension is much less complex than for the planning period. We have assumed that the following components of demand are fixed at 2044/45 levels throughout the 15-year extension:

- total leakage, including supply pipe leakage;
- water taken unbilled; and
- distribution system operational use.

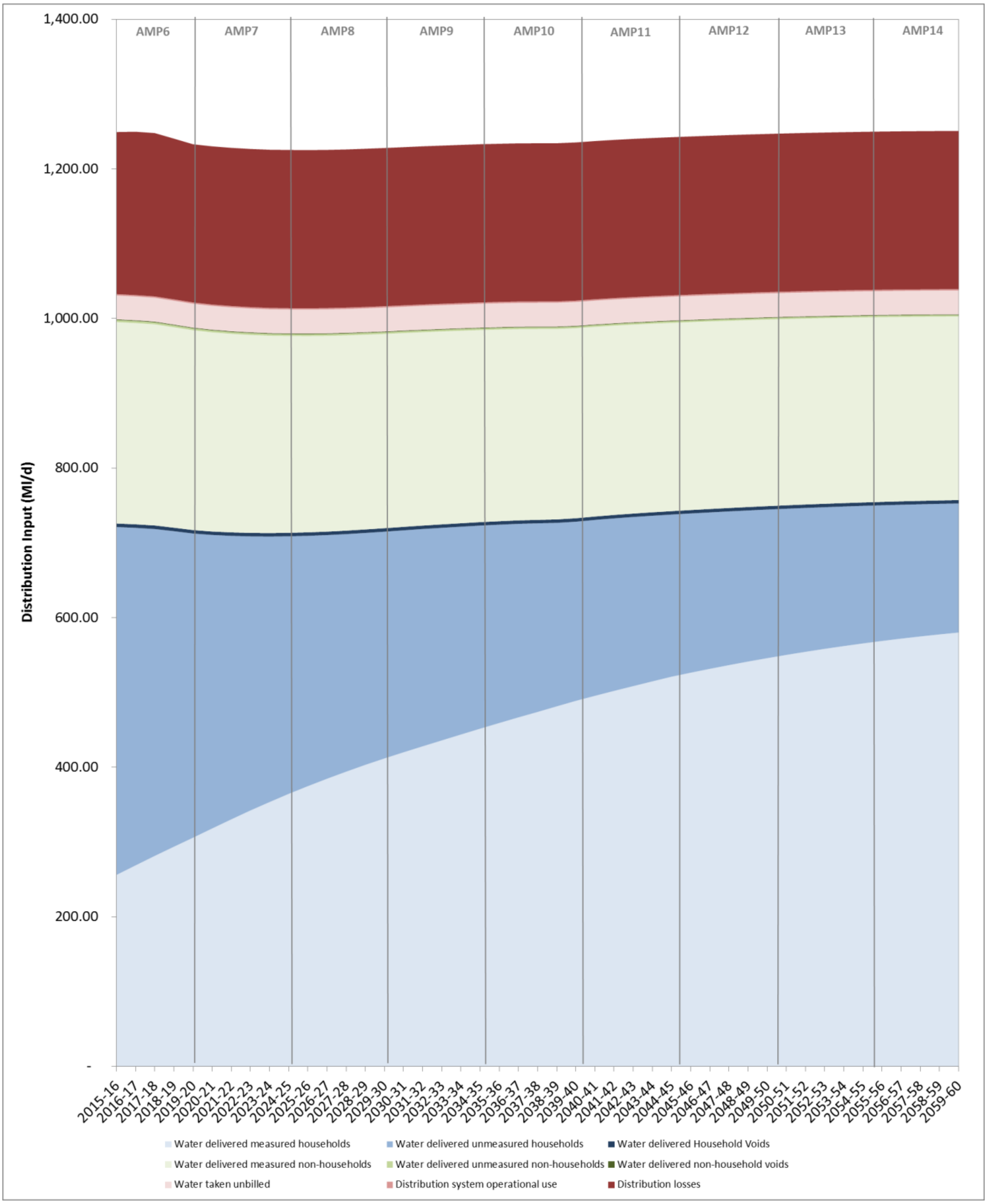
The only components of demand to vary are consumption of the different property categories, for which we have continued the observed trends calculated for the planning period.

Table 4.17 and Figure 4.16 show the extended demand forecast to 2059/60.

Table 4.17 Distribution input for the extended planning period

Distribution Input	2015-16 (Base Year)	2044-45 (end AMP11)	2049-50 (end AMP12)	2054-55 (end AMP13)	2059-60 (end AMP14)
Grid SWZ	1,242.85	1,236.37	1,240.76	1,243.57	1,244.77
East SWZ	6.38	5.94	5.92	5.91	5.90
Total	**1,249.23**	**1,242.31**	**1,246.68**	**1,249.47**	**1,250.66**

Figure 4.16 Total distribution input for extended planning period



5 Leakage forecast

This section describes how we have forecast the leakage component of our demand forecast. It describes our assessment of our baseline leakage position, estimation of SELL through economic appraisal and future leakage targets.

This section provides a summary of our baseline and future leakage position. Further detail is given in our supporting document Demand Forecast Technical Report which has been provided to the Environment Agency and is available on request.

We have determined a baseline leakage scenario for the WRMP19 based on the Sustainable Economic Level of Leakage (SELL). This is the point at which the cost to repair leaks, including the carbon and social costs of leakage control, is equal to the cost to treat water including the social, environmental and carbon costs. At this point, there is no overall economic benefit in reducing leakage further.

If a water resource zone is found to be in deficit, we consider further leakage reduction as part of the solution to maintain the supply demand balance. The final planning leakage scenario is calculated using the outcome of this options analysis. In WRMP14 we opted to reduce leakage during AMP6, as the most sustainable economic option to mitigate a forecast supply demand deficit.

The AMP6 regional leakage target in WRMP14 are shown in Table 5.1 below.

Table 5.1 AMP6 regional leakage target

Year	2015/16	2016/17	2017/18	2018/19	2019/20
Leakage Target (Ml/d)	297.1	297.1	297.1	292.1	287.1

We have reviewed our SELL for WRMP19, through analysis of leakage reduction activity and cost data recorded in recent years.

5.1 Consistent leakage reporting

During AMP6, Water UK and the UK water companies have worked together to derive a more consistent method for reporting leakage. The outcome of this work has been published in the report *Consistency of Reporting Performance Measures* (UKWIR, 2017).

For the remainder of AMP6, water companies are required to report leakage performance following existing reporting methodology and ‘shadow report’ total leakage in accordance with the consistent methods.

We have fully applied the calculation changes, combined with our planned data improvements, to both 2015/16 data for use in our WRMP19 leakage forecast and SELL calculation, and to 2016/17 data for shadow reporting. However, to be fully compliant with consistency of reporting we require additional monitoring to increase sample sizes in 5 of the 16 data quality measures described within the UKWIR report. The full impact of these changes on our reported leakage figure is not yet known.

In 2015/16 the actual leakage reported was 285.11Ml/d. This was recalculated using consistent reporting methods to 293.71Ml/d, an increase of 3%. In 2016/17, the actual leakage reported was 295.17Ml/d, against a target of 297.1Ml/d. This was recalculated using consistent reporting methodology to 296.56Ml/d for shadow reporting, an increase of 0.5%. Consistency of reporting had little impact on the components of the water balance in these two years, but the impact is also not consistent between the years.

We have an ongoing leakage data improvement plan, much of which supports progress towards leakage consistency reporting. A number of components of the water balance, such as estimates of plumbing losses, unmeasured non-household consumption and meter under registration have been reviewed.

Additionally, an occupancy model for improved estimation of household night use allowance and PCC developed. These improvements have been applied to historic data as part of the consistent reporting used in the leakage calculations and economics for the WRMP19.

5.2 Estimating total leakage

Total leakage is estimated as the sum of distribution losses plus leakage from customer owned supply pipes. Distribution losses are leakage within our mains network and include losses from large trunk mains and service reservoirs. The components of total leakage reported following consistent measures are presented in Table 5.2 below.

Table 5.2 Consistent reporting leakage volumes

	2015/16 Consistent Volume Ml/d	2016/17 Consistent Volume Ml/d	2017/18 Consistent Volume Ml/d
Trunk mains and service reservoir losses	45.13	51.10	48.98
Distribution losses excluding trunk mains and service reservoirs	170.35	168.73	169.08
Customer supply pipe leakage	78.23	76.73	78.31
Total	**293.71**	**296.56**	**296.37**

5.2.1 Distribution losses

We continually monitor leakage to target leakage management activities. The distribution network has been divided into approximately 2,400 Distribution Management Areas (DMAs), with an average size of approximately 930 properties.

Approximately 98% of these DMAs are permanently metered and have flows in and out of the area recorded every 15 minutes, from which a nightline can be derived.

We aspire to establish 100% coverage, however we also recognise this may not be economically viable, particularly in areas with complex supply systems, such as some city centres.

Monitoring of night-time flows within DMAs, when usage is at its lowest, allows derivation of leakage estimates. Permanent loggers are installed on DMA meters. Most are telemetered loggers, using GPRS technology, which enables DMA flow data to be gathered every 30 minutes for operational purposes and twice daily for leakage purposes.

This data is processed by our leakage and pressure monitoring system Netbase, which calculates the level of leakage in each DMA. For consistent reporting, the average of the seven-day night flow taken between 3am and 4am is used to produce the DMA weekly leakage level aggregated for annual figures.

An allowance for household and non-household night use is subtracted from the average gross nightline to produce the average net nightline. Large night users are logged, and the logged data subtracted from the DMA net nightline. This is the best estimate of all the leakage within the DMA, including supply pipe leakage.

Where properties are not within an established DMA, and are therefore not monitored, we undertake a full sounding of the area each year to identify potential leakage.

Leakage detection staff use a variety of traditional techniques such as sounding of fittings, step-tests, correlator surveys, acoustic noise logger surveys and more innovative techniques, such as the use of satellite imaging.

Repairs are carried out by a service partner. All repair jobs are tracked in our operational reporting database, so that repair times and backlogs are closely monitored.

5.2.2 Trunk mains losses

Trunk mains are defined as all mains between the treatment works outlet and the inlet to DMAs and include distribution of water to and from service reservoirs. We have 4,278km of trunk mains. Each year we carry out flow balances on a sample of

the trunk mains network. The number of successful flow balances is increasing annually, from 7.8% of our trunk main length in 2009/10 to 17.8% in 2016/17. For consistent reporting in 2015/16 we calculated trunk main losses to be 10.11 m3/km/d which is 43.26Ml/d.

Trunk main detection and repair has historically been mainly reactive due to the difficulties in identifying and pinpointing trunk main leakage. Recent improvements in correlating technology have enabled proactive detection and repair.

5.2.3 Service reservoir losses

There are two components of service reservoir losses; structural leakage and losses due to overflow. Location of service reservoir leakage is part of our service reservoir maintenance programme. This is a rolling programme of cleaning and inspection based on factors including water quality compliance, asset age, date of last refurbishment and known structural faults.

Following cleaning and inspection a drop test is carried out on the refilled service reservoir to assess leakage. The reservoir is filled, inlets and outlets are shut off, and changes in water level over 24 hours are recorded; any drop in level will indicate a leak. Under the rolling inspection programme, all service reservoirs are assessed for leakage every one to five years. Those reservoirs with the highest risk of leakage or ingress are prioritised for assessment.

As well as losses through the structure of service reservoirs, water can be lost through reservoir overflows. The volume of water lost through a period of overflow is estimated from the duration of high alarm events at service reservoir sites.

5.2.4 Customer supply pipe leakage

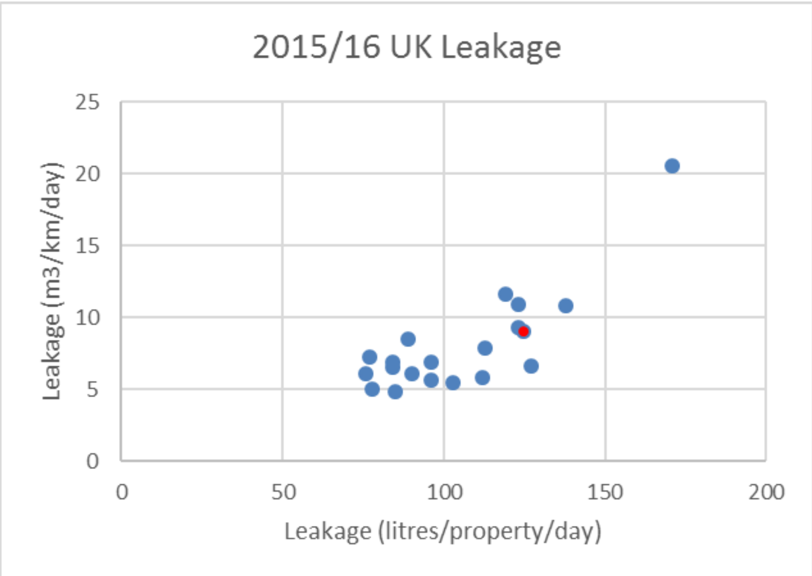
The total volume of supply pipe leakage is estimated to be 31.2% of leakage within DMAs. This was calculated from an assessment of properties on our Domestic Consumption Monitor survey. We are carrying out research into supply pipe leakage and this may improve future leakage analysis.

We provide a free repair service for all domestic supply pipes which are not under buildings. Domestic customers can claim one free repair in a two-year period. We also provide a commercial service for detection and repair of any commercial supply pipe leaks.

5.3 Industry position

We have reviewed our leakage performance against other water companies in England and Wales, as measured in litres per property per day and cubic metres per kilometre of mains length per day. Our relative position (shown by the red data point) in terms of these two measures is shown in figure 5.1. This shows that our current leakage performance is at the lower end of current UK water industry performance, for both measures.

Figure 5.1 UK reported water company leakage



It is still unclear exactly how this position will differ once all companies report leakage following the consistency of reporting methodology.

The International Leakage Index (ILI) is used to compare performance internationally. It looks at the company assets to calculate unavoidable leakage and then compares the ratio of actual leakage to calculated unavoidable leakage.

Our 2015/16 consistently reported leakage ILI is 1.89, so is in the best performing third of the European High-Income companies. This is ranked as Leakage Performance Category A2 by the World Bank.

In both the UK and internationally, lower leakage levels are achieved by companies with a supply demand deficit, high cost of water and high levels of meter penetration. We are not currently in this situation but aspire to reduce leakage as part of our preferred plan to increase resilience and flexibility of water supplies in the future.

5.4 Leakage economic appraisal

We have adopted the water company specific recommendations from the *Review of the calculation of sustainable economic level of leakage and its integration with water resource management planning*, (SMC, 2012). Since WRMP14 we have made significant improvements in our accounting of the cost and benefit of active leakage control, so we now have robust data for analysis.

For this WRMP we carried out a leakage economic appraisal to provide the following information:

- calculation of the short-run SELL using 2015/16 reported leakage;
- calculation of the short-run SELL using the consistency of reporting methodology for 2015/16; and
- cost of leakage reduction options to meet a supply demand deficit.

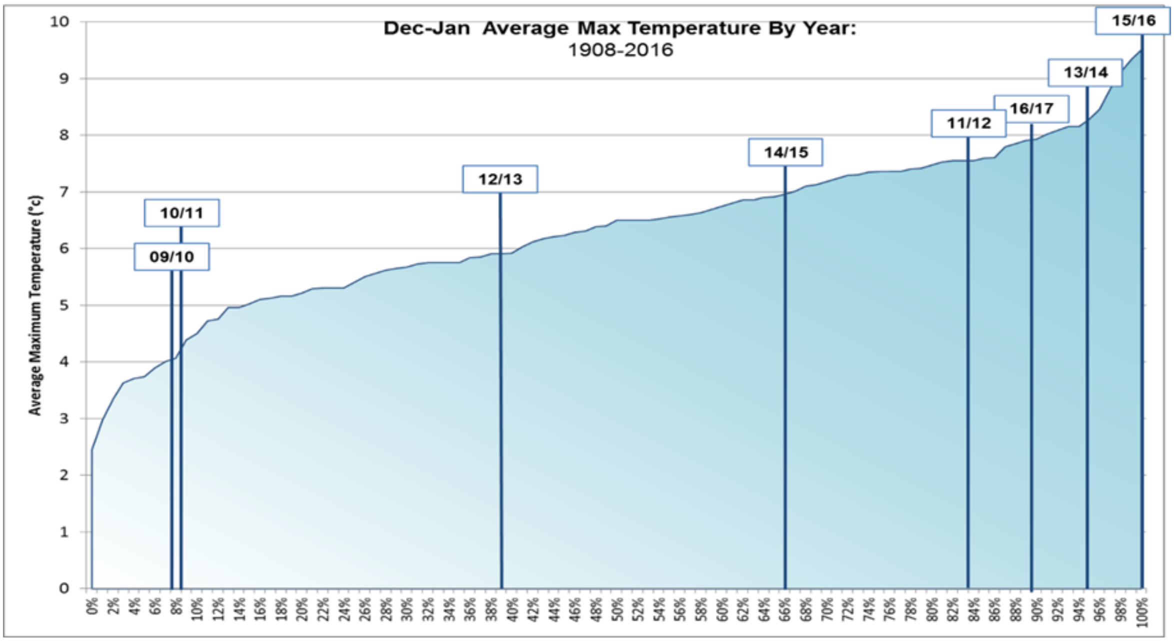
The SELL is the economic level of leakage including the environmental and social costs of leakage and leakage reduction.

Updated modelling of the SELL was carried out by RPS Water consultancy, using consistent leakage data and other Yorkshire Water specific cost data from the baseline year 2015/16. Environmental, social and carbon costs of leakage control were determined using appropriate methodologies to align with *Providing Best Practice Guidance on the Inclusion of Externalities in the ELL Calculation* (Ofwat/RPS, 2008).

The total cost of leakage and leakage reduction for different leakage levels has been calculated. The SELL is the level of leakage at which the total cost is at a minimum.

This information was used to calculate the baseline leakage position for the 25-year planning period from 2015/16 to 2044/45. This was complicated because 2015/16 was not a representative year, with an atypically mild winter compared with winters over the past 100 years, as shown in figure 5.2 below.

Figure 5.2 Average minimum temperature 1908 - 2016



5.5 Baseline leakage forecast

The analysis using 2015/16 reported leakage figures, assuming a starting point of 287.1Ml/d (the 2019/20 leakage target), calculated SELL as 297.44Ml/d.

The analysis using 2015/16 operational and cost data, but with leakage figures adjusted to consistent reporting and incorporating AMP7 data improvements, calculated SELL to be 280.32Ml/d. The reason this is so different from reported leakage SELL is the increasing volatility of consistent reported leakage data. Reported leakage data shows we did not target any detection and repair activity at very low levels of leakage, but because consistent leakage data was not used for targeting the consistent leakage data shows activity at lower levels of leakage.

We have routinely established a cost-benefit relationship for detection and detected repairs for all previous years. However, until consistent leakage data is used to determine this activity, the level of volatility means it is inappropriate to use this cost-benefit relationship for future planning.

5.5.1 Impact of non-leakage activity on baseline leakage

We have assessed the potential impact of activity carried out in our distribution on leakage and SELL.

Mains renewal for burst reduction or water quality drivers will not have a significant impact on leakage reduction. In 2012, we undertook significant mains renewal activity to address 17 high burst rate and high leakage DMAs in Leeds. This was successful at reducing burst rate and the cost of leakage control in future years but did not show any discernible leakage reduction.

During AMP7 we plan to renew 0.3% of water mains/year to maintain asset reliability and burst frequencies.

Increasing meter penetration does not have a notable impact on leakage targets or the SELL calculation because, although it is likely to result in customers reporting lower volume supply pipe leakage and hence a 0.6% reduction in leakage, repair of these supply pipes increases repair costs per Ml/d saved.

Property growth is expected to continue at 20,000 properties per year. We have carried out detailed investigation into distribution leakage levels in new build housing estates and found leakage between the DMA meter and the household meters at the edge of the customer’s supply pipes to be 50 litres per property per day. This is much higher than expected as it does not include trunk main leakage or supply pipe leakage. Further investigations are ongoing, because this indicates that leakage increase due to property growth is predicted at 0.3% per year.

Innovation is necessary to ensure that detection and repair costs are achievable at much lower levels of leakage than the basis of the current model. The 2015/16 data incorporates all our improved methods of leakage management and the benefits of pressure management activity carried out in the preceding years.

Our ongoing data improvement plan uses new and emerging methods of accounting for leakage to help separate leakage from demand, to improve our targeting of leakage management activities. We have assessed known new techniques for inclusion in our plan, and continuously pursue more innovative options. The efficiency this will deliver is unpredictable and is likely to be insignificant compared to the increased cost of moving to, and maintaining, aspirational leakage levels.

If we are to achieve an aspirational leakage reduction, this will require new and alternative techniques. For example, we have previously identified that the level of background leakage due to 'weeps' and 'seeps' is a key limiting factor in both leakage reduction and the prohibitive cost of leakage reduction. We commissioned a consultant to look at alternative options for sealing 'weeps' and' seeps', but with limited success.

5.6 Final planning leakage forecast

As noted above, our current leakage performance is at the lower end of UK water industry performance. We know that our customers want us to reduce leakage, particularly when they are given information about our performance in comparison to other companies. Further, there have been clear government and regulatory signals about the need for the industry as a whole to reduce leakage. So not only do we need to improve our performance when measured against the current performance of the rest of the industry, we also expect the rest of the industry to improve as well.

Therefore, although we are not forecasting a supply/demand deficit until 2024/35, we have set ourselves an ambitious plan to reduce leakage by 40% by 2025, from 297.1Ml/d to 175.1Ml/d. We have identified, costed and quantified a series of feasible options to deliver this reduction, which will reduce leakage below the SELL.

This is included in Section 9 and includes our approach to alternative techniques to traditional 'find and fix' such as pressure management and DMA optimisation. It also details our approach to targeting trunk main and supply pipe leakage.

6 Water efficiency and demand reduction strategy

This section describes how we intend to continue promoting water efficiency to our customers and investigate new innovative measures for reducing demand in the future.

Water efficiency is an integral part of water resource planning for the future. Water companies have had a duty to promote the efficient use of water to all customers since 1996, and its importance increases as the risks to water and energy supply increase. By promoting water saving benefits to our customers, reducing our own use of water in the production of potable and treatment of wastewater and building partnerships we can help keep demand low and reduce our reliance on natural resources.

Our long-term strategy, which was published in March 2018, sets goals for us to meet future challenges to clean and waste water services and meet our customers' expectations. Our goal for water supply is that we will always provide our customers with enough safe water, we will not waste water and always protect the environment.

The key themes of our water efficiency strategy are:

- communicating the water efficiency message to our customers; and
- a continued drive for innovation and best practice to reduce demand for water.

We continue to actively promote water saving to our customers through household water efficiency initiatives. The Water Act 2014 introduced non-household water retail competition in England in April 2017. Since retail separation, Yorkshire Water is responsible for wholesale water supply and household retail in the Yorkshire region but not non-household retail services. Non-household billing and customer

service provision is delivered by a number of retailers operating in the Yorkshire Water region.

Although we are no longer directly supplying non-household customers in our region, we still have a responsibility to promote water efficiency to commercial water users. We are looking at new and innovative means of working with this sector to help reduce their water use. This could include working in collaboration with retailers in our region or offering commercial users new services, such as non-potable water supplies from recycled water, described in more detail below.

6.1 Household customer water efficiency

Our household customer water efficiency strategy is summarised below:

- Water saving packs - household customers can request free water saving packs. The products offered are a flow reducing showersave, cistern displacement device, shower timer, tap inserts and self-audit leaflet. Customers can select which products they would like to receive.
- Household audit and retrofit service - customers will be offered our 'Fit2Save' service where a technician will visit properties and fit appropriate water saving devices.
- Promotion and sales of water butts to customers - discounted water butts are available to customers through our website.
- Behavioural change – we encourage behaviour changes through:
  - Water efficiency information on our website including a water use calculator
  - Water efficiency tips and self-audit leaflets
  - The Green Classroom school pack and visits to our education centres.

In recent years, we have focused our household customer water saving activity on the provision of free water saving packs that customers self-fit. This has been successful in our region, with free pack giveaways of 30,000 to 40,000 per year.

Recent studies, including a Yorkshire Water project in the Huddersfield area, have concluded the free packs do not achieve the savings originally assigned to them in annual reporting assumptions provided by Ofwat in AMP5. Our project concluded that savings were no more than five litres per property per day (l/p/d), compared to around 50 l/p/d previously assumed. This can, in part, be attributed to the fact that customers ordering the free packs do not necessarily fit the products.

From 2018 to 2020 we are delivering a trial project where we offer to visit customers' properties and fit water saving devices free of charge. If successful we will continue to offer this service from 2020 onwards.

We will also continue to offer the free self-fit packs, but at a lower promotional level. This assumes that customers who actively seek to order the free packs are more likely to fit them and therefore achieve savings.

6.2 Communication campaign strategy

We are taking a new approach to our behaviour change campaigns to make sure we are reaching the right customers with the right messages, at the right time. We will use our customer insight to identify how different segments of customers use water in different ways, and what messages and incentives are most likely to change their behaviour and attitude to water and the amount they use.

In the past, we have delivered broad awareness campaigns across the whole of the region, to encourage customers to use less water and to promote our free water saving packs. We are now moving to a more "micro" approach to talk to different communities in the right way, at the right time. We hope to see a real change in behaviour and to promote positive attitudes at a household and community level.

Using Experian data, we have identified the different demographics of our customer base in Yorkshire, in total we have nine 'Mosaic' types and all the types have different characteristics, attitudes, income, locations etc. We use the Mosaic types to get to know our customers more and identify the right channels to use and what messages they might be interested in.

The Experian data has helped us identify which four of the nine Mosaic types have the highest water consumption. These are:

- **'Starting Out'** (young families likely to have a couple of children, living in semi-detached and terraced properties with lower to mid-affluence);
- **'Affluent Families'** (families likely to have children, living in larger detached properties in suburban areas of Yorkshire);
- **'Urban Families'** (families likely to have more than 2 adults living at home, living in semi-detached and terraced properties with slightly different habits and behaviour where water usage is concerned); and
- **'Rural Retirees'** (people aged 60+ living alone or in couples in detached properties in rural areas whose children have left home).

Using this insight, we know the parts of our region these segments of customers are most likely to live and can target these customers using channels that will appeal to each individual segment. For example, we will use local newspapers and village halls for 'Rural Retirees' to maximise engagement. For 'Affluent Families', we might use social media for targeted messaging.

We will also change the messaging of the campaign to suit each segment, as the insight helps us to understand both current situations and what the drivers for saving water might be. As an example, we might emphasise the impact on the environment and the future of our region to influence 'Affluent Families' behaviour and attitudes to water. For 'Urban Families', we might talk about the direct impact on them and potentially their bills as this would be a more compelling reason for them to use less water.

In addition to different messaging, we will also have different packs, giveaways and offers for each segment. For 'Starting Out' families we will offer child friendly packs, targeted to people with young children who may need to save both time and money. We will encourage uptake through product giveaways or competition prizes that will benefit customer group. For 'Starting out' this could be 'Bath Buoys' or 'Baby Dams'. For the 'Rural Retirees' segment we will run similar competitions and offers but for gardening items such as water butts or watering cans.

The customer segmentation approach has identified that the ‘Starting Out’ segment are most likely to respond to a home water audit offer. When we trial the visit and fit service, we will offer it in areas that include this segment of customers and include messaging and incentives that are likely to appeal to the starting out segment. We will track the success of the visits over the course of the campaign and if the feedback is successful in terms of the customers’ experience during the visits, we will trial this approach across some of the different segments.

We will also promote the customer campaign and home audit trials in areas of our Grid SWZ with potential risks to resilience, to help prevent this becoming a pressure on our water supply.

6.3 Free supply-pipe repairs

We continue to offer free supply pipe repairs, to ensure that supply pipe leakage is kept to a minimum. This contributes to a reduction in demand.

Our policy is to raise customer awareness of supply pipe ownership and give options to manage the associated responsibility. Under the policy we repair a leaking supply pipe free of charge for household customers, however further repairs are at the customer’s own expense for two years following repair.

6.4 Metering

We operate a free meter option scheme. Details of the scheme are given on our website. This includes a water use calculator to allow customers to calculate their likely water bill on a metered supply. A forecast of domestic meter optants is included in the demand forecast. Further details are provided in Section 4.4.1 of this plan.

Water savings are typically seen after the installation of a meter, due to the increased financial incentive to use less water. These savings are a major contribution to water efficiency.

Currently around 50% of our household customers have a metered supply. We are forecasting an average of 34,054 optants per year from 2015/16 to 2019/20, which is the average number of optants in the previous 5 years. This is forecast to

decrease gradually to 15,000 per annum by 2030/31 and remain fixed at this rate for the remainder of the planning period, reflecting the decreasing number of unmeasured households available to opt, and with a financial benefit of opting.

At this point the potential number of optants per year becomes increasingly uncertain due to the increasingly unpredictable nature of the remaining unmeasured household property base in terms of meter opting. This is a forecast based on assumed activity and will be reappraised and reassessed for WRMP24 based on optant activity in AMP7 and any changes to our metering policy at that time.

By 2044/45 we are predicting 64% of base year unmeasured household properties will have opted to be metered. Including all new properties, which are metered as a legal standard, we are forecasting 84% household metering by 2044/45.

Metering is instinctively an appropriate method of charging for water and sewerage, based on payment for use. However, metering is expensive compared to unmeasured billing and would significantly increase customers' bills through the additional cost of the meter, a replacement cost every 10 to 15 years and the ongoing operating costs of servicing a measured account. The cost of metering coupled with a policy of maintaining an element of customer choice, results in a continued policy of demand led (meter optant) household metering in Yorkshire.

6.5 Selective metering

Selective metering is the installation of meters at existing billed household properties where a customer has not chosen to have a meter fitted.

Under the Water Act 1991, we can selectively meter properties when there is a change of occupier or at properties that meet certain criteria for water use. For example, if the water supply to a property is used to automatically refill a pond or swimming pool with capacity greater than 10,000 litres or for watering a gardening with a fixed irrigation system.

Currently we do not have a policy of selective metering in either circumstance, and therefore we have no associated water savings for this category. However, one of

the investment options considered for WRMP19 is a scheme for metering properties on change of occupancy.

6.6 Tariffs

We have considered the use of tariffs as a potential demand management option. We have investigated the use of social tariffs but this impacts on the 'retail' element of the bill and is not based on varying tariffs for different levels of water use.

Use of tariffs for demand management would require properties to be metered to allow a financial benefit for reduced water use. Current meter penetration in Yorkshire is just over 50%, and therefore we consider the use of tariffs for demand management to be an unfeasible option at this stage.

We also have insufficient information to quantify the potential water savings from tariff schemes for WRMP19.

6.7 Sub potable water supply

We aim to provide our customers with a sustainable and affordable water supply for the future. By reusing and recycling water that has already been used in supply, we can reduce the water we are required to take from the environment to meet our customers' needs. This reduces the overall demand for water, and the need for investment in new assets and infrastructure for both clean and waste water services.

Similarly, potable water for some purposes can be replaced with grey water or rainwater. This can be for household as well as non-household use, for example flushing toilets or watering gardens.

6.7.1 Final effluent reuse

We are investigating how to reuse and recycle existing water supplies for use by non-household water users. We can do this by substituting potable water supplies with non-potable water supplies where it is appropriate.

For example, the combined use of industries in Hull is over 7 billion litres of potable water every year, most of which is for industrial cooling down processes. By using non-potable water for these processes, we could offset 5% of our total potable water production.

Over the next two years we will be trialling a number of projects to understand how we can supply non-potable water to non-household partners across the region in a sustainable, safe and commercially viable way.

The non-potable supply will be provided by a nearby wastewater treatment works and piped direct to the non-household user. This will reduce the volume of potable water we treat and supply to these companies, which reduces our total chemical and energy requirements during the production of potable water. The water supply will be separate to the companies' potable supply and only used for specific purposes where non-potable water is suitable.

There are three small pilot schemes proposed for delivery between 2018 and 2020. The first scheme will be implemented at one of our own waste water treatment works in South Yorkshire. It will use final effluent for a stage of treatment that traditionally utilises potable water. If successful, this could be repeated at several of our other waste water treatment works.

Secondly, pilot projects are planned with two companies in our region to use final effluent from nearby wastewater treatment works. This pilot will inform our future strategy and policy on sub potable water use and help determine the commercial and regulatory viability of these policies and practices for delivery on a wider scale.

The third project is planned for one of our largest wastewater treatment works in the Bradford area. This project has two deliverables; firstly, the land surrounding the works has the potential to be developed for domestic, industrial and amenity value. Our Innovation Team is developing a plan for these developments to be exemplars of sustainability and case studies for circular economy application. The developments will aim to maximise water reuse, using a variety of approaches including sub-potable water systems, delivering a significant reduction in household consumption and potable water offset in industry.

Secondly the works will demonstrate the capabilities of new and emerging technologies to produce water across a variety of standards, informing the range of water products available to non-household customers and options to consider for additional water treatment facilities in the future.

All three schemes will inform how we supply non-potable water to non-household partners across the region in a sustainable, safe and commercially viable way. These schemes will achieve relatively small savings on the volume of water we abstract for potable supply per a year. However, the learning from the projects will be used to offer the service to larger water users and we have identified a company that could potentially use nearly 20Ml/d of non-potable water.

6.7.2 Integrated Water Management

As the population in our region increases there will be more requirement for new housing developments. This will increase future demand for water and put pressure on our waste water network and treatment processes if we do not invest in new assets and infrastructure.

To reduce investment in new assets and infrastructure we are proposing to work with developers to provide a non-potable water supply for two new settlements planned in the Leeds and Harrogate areas. Approximately 4,000 new houses are proposed for the Leeds development, construction will be carried out over several years with 1,850 houses to be built by 2028. Development beyond that date is dependent on local planning permissions. Around 3,000 houses are planned for the Harrogate settlement.

To meet water demands, options are available to connect the properties to existing water supplies. For the treatment of waste water, a new waste water treatment works is likely to be required and additional infrastructure for transporting, storing and pumping waste water before treatment.

Alongside traditional methods for delivering and disposing of water to customers, Integrated Water Management (IWM) has been considered. IWM is the management of the water cycle (water efficiency, potable water demands, non-potable water demands, surface water, wastewater and water supply) in harmony

with the built environment through planning and urban design. Within this approach the water cycle is considered from the outset and throughout the planning and design process for developments.

Water management approaches involve:

- understanding of the local constraints, such as local environment, infrastructure capacity and available space;
- making the best use of existing infrastructure and delaying or minimising the need for reinforcements and upgrades; and
- provision of resource security and greater resilience in the future.

IWM approaches can deliver multiple benefits, including reduced cost of water abstraction and treatment, reduced pumping of potable water and wastewater, increased headroom in water supply and drainage networks, and reduced footprint of wastewater treatment plants.

The IWM approach aims to meet the demands for water that can be satisfied by non-potable quality water. There are several processes available and the approaches considered for the Leeds development included:

- higher water efficiency measures - based on Building Regulations Part G and assumed water demand of 105 l/d per person;
- rainwater harvesting – supply of rainwater from rooftops for non-potable water use;
- stormwater harvesting – use rainwater from catchment surfaces for non-potable water use; and
- greywater reuse – recycle water used for domestic purposes such as showering and dishwashing for non-potable water use.

We are currently working with the developers of the housing projects to include provision of some of the above techniques during the construction of the new properties. This will reduce the waste water infrastructure requirements for the development. It will not change the requirement for connecting the properties to a potable water supply, but will reduce the volume of water we abstract, treat and

pump to these customers. The homeowners are likely to save on their water bills if non-potable water is supplied at a rate below the potable water supply.

6.8 Reducing our own water use

Our long-term goal for water supply aims to reduce the water that we use, and the water that is lost through leakage. We will use innovation to help us drive down the cost of identifying and repairing leaks so that we save water and money. Our sub-potable use trial at a waste water treatment works will provide an understanding of how we can make more use of final effluent instead of potable water in waste water treatment.

The feasible options for this WRMP19 include several options for reducing our own use of water during the process of producing potable water at our clean treatment works. Our PR19 performance commitments include a recycling commitment. This is discussed as part of our final planning scenario in Section 12.

6.9 Water efficiency options

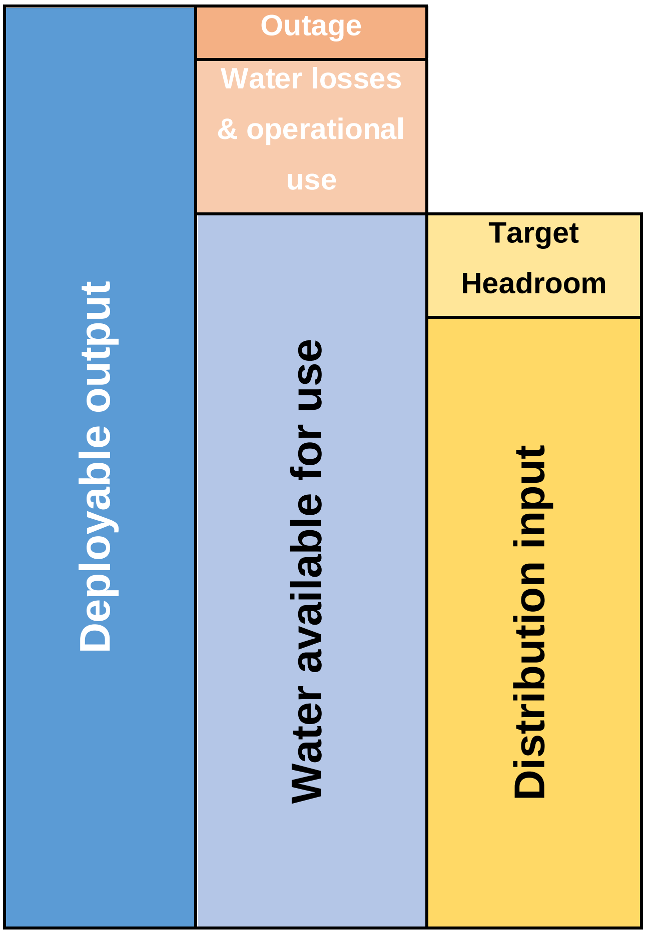
Customer side management options have also been included in the feasible options available to meet a supply demand gap. This includes; increased metering, including metering on change of occupancy; plumbing loss benefits linked to supply pipe leakage reduction options; and an enhanced home water use audit service delivered to a greater number of households each year.

7 Allowing for uncertainty

Headroom is an accepted term in the water industry to define a planning allowance to account for uncertainties that could have a permanent impact on the water balance in the future. We calculate target headroom to provide a buffer between forecast supply and forecast demand. The headroom planning allowance is separate to the outage planning allowance, as outage accounts for temporary reductions in supply.

Further detail on our approach to uncertainty is provided in a supporting document Uncertainty Technical Report, which has been provided to the Environment Agency and is available upon request.

Figure 7.1 Supply demand balance components



We calculate target headroom and available headroom to ensure demand will be met over the 25-year planning period. Available headroom is the water available once the forecast demand is met. Target headroom is a buffer we allow between supply and demand for specified uncertainties that impact permanently on our ability to meet demand in a water resource zone.

Figure 7.1 shows target headroom as a component in the supply demand balance. We must ensure WAFU is greater or equal to distribution input plus target headroom throughout the planning period. If WAFU is less than distribution input plus target headroom, measures must be taken to ensure the deficit will be met.

As for previous plans, we have calculated target headroom following the UKWIR guidance *An Improved Methodology for Assessing Headroom* (UKWIR, 2002) and used a stochastic model to produce an estimate of target headroom at a range of percentiles. This is included in the UKWIR *WRMP 2019 Methods – risk based planning guidance* (Atkins, 2016) as an accepted methodology for calculating target headroom.

The East SWZ supply demand forecast showed a surplus throughout the WRMP14 planning period and our problem characterisation concluded that the traditional target headroom method was appropriate.

The Grid SWZ was initially classed as small strategic needs with high complexity in its problem characterisation, due to climate change driving a deficit for WRMP14 and a risk of sustainability reductions increasing the deficit in WRMP19. We therefore considered if a “scenario based method” headroom approach was appropriate. It has since been confirmed that there are no defined sustainability reduction scenarios which would drive a deficit in the zone and supply side climate change is the only risk driving a deficit in WRMP19.

We therefore considered it most appropriate to use the UKWIR 2002 headroom methodology for the Grid SWZ target headroom. We do, however, include an alternative, more extreme climate change scenario, in our sensitivity testing for the zone.

We assessed the supply demand balance in this plan at target headroom values to ensure the security of supply is maintained at the current levels of service. This assessment is in line with the Intermediate Approach presented in the *Economics of Balancing Supply and Demand Methodology* (UKWIR, 2003)

The UKWIR 2002 headroom methodology prescribes a probabilistic approach to assessing headroom, applying probability distributions to individual headroom components. We use a stochastic model to derive the target headroom for the 25-year planning period. Headroom components are based on known risks to supply and collated in consultation with key Yorkshire Water staff.

7.1 Headroom components

Headroom components can be divided into two categories, those that represent the uncertainties in the supply forecast and those that represent the uncertainties in the demand forecast. We consider headroom components for each water resource zone individually, to provide target headroom values for the dry year annual average scenario for each zone.

Table 7.1 shows the headroom components we considered for each zone based on the UKWIR 2002 methodology. In accordance with *the Water Resources Planning Guideline,* we do not include uncertainty due to unconfirmed sustainability reductions.

We have not identified any vulnerable surface water headroom risks in either zone over the planning period and no vulnerable groundwater risks in the East SWZ. There is one vulnerable groundwater source in the Grid SWZ and 14 groundwater headroom risks due to pollution. This includes nitrates, pesticides, saline intrusion, bacterial contamination and cryptosporidium. Some sites are affected by more than one risk, and interdependencies are accounted for in the headroom assessment to ensure no double counting.

We included uncertainty due to the impact of climate change on source yields in the Grid SWZ and East SWZ headroom estimates. This was based on the methodology applied to both zones in the deployable output climate change assessment. For each of the two zones, the analysis produced climate change forecasts over a range

of 20 scenarios, with probabilities assigned according to likelihood of the UKCP09 projections. The climate change headroom component was calculated from the difference between the selected (baseline) deployable output scenario and the deployable output produced by the 20 scenarios. This difference and the weighting of each scenario was used to provide a discrete distribution to represent the uncertainty of climate change on yield in the *Crystal Ball* probability model.

We have also calculated headroom without the impact of climate change to understand how much this component contributes to the total target headroom values.

Table 7.1 Headroom components assessed for each water resource zone

Headroom component	East SWZ	Grid SWZ
S1 Vulnerable surface water licences	N/A	N/A
S2 Vulnerable groundwater licences	N/A	Included
S3 Time limited licences	N/A	No risks identified
S4 Bulk transfers	N/A	Included
S5 Gradual pollution	N/A	Included
S6 Accuracy of supply side data	Included	Included
S8 Climate change impact on supply	Included	Included
D1 Accuracy of sub-component data	Included	Included
D2 Demand forecast variation	Included	Included
D3 Uncertainty of impact of climate change on demand	Included	Included

The Grid SWZ headroom calculation includes a component for uncertainty in the bulk raw water transfer from Severn Trent Water due to climate change.

Data accuracy impacts on the overall headroom for each zone. Supply data accuracy uncertainty in surface water zones is due to measurement errors in river flow data and climatic variations. In both the Grid SWZ and the East SWZ we estimate the uncertainty due to supply data accuracy is between +6% and 10% of WAFU throughout the planning period.

Uncertainty in the demand forecast has been applied to both water resource zones. We attribute the uncertainty in demand data accuracy to measurement error. Demand is measured by recording the volume of water going into supply, known as distribution input. The meters we use to record distribution input have an accuracy specification of +/- 2%. Therefore, for both zones, we estimate demand data accuracy to increase or decrease distribution input by up to 2%. We have maintained this accuracy over the planning period.

We account for uncertainty in our forecast demand for household and non-household properties. For households, we have considered uncertainty in our forecasts of domestic meter optants, per capita consumption and population. For non-households, we have considered uncertainty in future growth or decline in service and non-service sectors, based on modelled scenarios.

All estimated uncertainty for household and non-household properties are combined into one component known as demand forecast variation.

The demand forecast also includes an assumption on the change in water use due to climate change. The headroom assessment component allows for + / - 50% uncertainty of the increase built into the baseline demand forecast.

7.2 Target headroom calculation

We assign probability distributions in the stochastic model to represent the uncertainties of each individual headroom component. The model calculates target headroom at five-year intervals between 2020/21 and 2044/45. It combines the probability distributions to produce headroom estimates for levels of certainty between zero and 100% in 5% increments.

A headroom estimate with a zero-percentile risk would provide no certainty that supply will meet demand over the planning period. Whereas, a 100th percentile risk would mean there is no risk that supply would not meet demand. The *A Re-evaluation of the Methodology for Assessing Headroom* (UKWIR, 2002) methodology does not include guidance on the percentile risk water companies should plan for in the supply demand balance.

The *Water Resources Planning Guideline* does not specify a level of target headroom certainty water companies should plan for but does state "If target headroom is too large it may drive unnecessary expenditure, if too little you may be unable to meet your planned level of service." It also advises companies to plan for a higher level of risk in the future compared to the early years. This assumes uncertainties will reduce and it is possible to adapt to changes over the longer term.

Since 1996, we have invested to provide minimum target headroom of 5% of WAFU. This follows recommendations from the *Water supply in Yorkshire. Report of the independent commission of inquiry* (Uff et al., 1996) to increase the supply demand planning margin following the impacts of the 1995/96 drought in Yorkshire.

For this WRMP we are basing the target headroom allowance on the output of the stochastic model.

Sensitivity checks have been carried out on the headroom probabilistic model to identify the components that make up the greatest proportion of headroom.

Table 7.2 and

Table 7.3 show the percentage contribution individual headroom components contribute to total headroom for each zone if we used the mid value for each component. This provides an indication of the weighting of the components in the target headroom calculation. These values will change dependent on the percentile we select for target headroom.

Table 7.2 East SWZ percentage contribution of individual headroom components to most likely total target headroom

Headroom component	Percentage contribution of component to most likely total target headroom					
	2020/21	2025/26	2030/31	2035/36	2040/41	2044/45
S6 Accuracy of supply side data	89.24	89.24	89.24	89.24	89.24	89.24
S8 Climate change impact	16.26	43.37	70.48	75.90	82.23	88.55

Headroom component	Percentage contribution of component to most likely total target headroom					
on supply						
D1 Accuracy of sub-component data	0	0	0	0	0	0
D2 Demand forecast variation	-5.50	-7.34	-7.34	-3.67	3.67	7.34
D3 Uncertainty of impact of climate change on demand	0	0	0	0	0	0

Table 7.3 Grid SWZ percentage contribution of individual headroom components to most likely total target headroom

Headroom component	Percentage contribution of component to most likely total target headroom					
	2020/21	2025/26	2030/31	2035/36	2040/41	2044/45
S2 Vulnerable groundwater licences	0.77	0.57	0.32	0.22	0.20	0.18
S4 Bulk transfers	0	0	0	0	0	0
S5 Gradual pollution	14.79	11.67	7.17	5.38	5.08	5.08
S6 Accuracy of supply side data	67.50	48.86	26.67	17.86	15.58	14.48
S8 Climate change impact on supply	22.64	44.50	67.62	76.43	77.18	76.66
D1 Accuracy of sub-component data	0	0	0	0	0	0
D2 Demand forecast	-5.81	-6.11	-2.75	-1.05	0.79	2.43

Headroom component	Percentage contribution of component to most likely total target headroom					
variation						
D3 Uncertainty of impact of climate change on demand	0	0	0	0	0	0

For both zones, the greatest risk is due to supply side components of uncertainty for data accuracy and climate change (S6 and S8). At the start of the planning period, accuracy of supply side data makes up the largest proportion of headroom in both zones. Climate change uncertainty becomes less certain over the planning period and is significantly increasing over the 25 years.

At the 50th percentile uncertainty level, by the end of the 25 years the East SWZ supply side climate change headroom uncertainty is equal to data inaccuracy. Whereas for the Grid SWZ supply side climate change results in a significant increase in headroom uncertainty, more than five times the uncertainty due to supply side data inaccuracy by 2045.

The East SWZ baseline scenario shows no change to deployable output due to climate change. The alternative climate change scenarios provided a headroom component with a 76% chance of no change due to climate change. From 2030 onwards, there is a low risk (less than 1%) of climate change reducing deployable output by more than 2Ml/d and a less than 2% chance of an impact greater than 0.6Ml/d throughout the planning period. The East SWZ supply demand balance has sufficient surplus to meet even the most extreme climate change scenario (see Section 8.1).

For the Grid SWZ the potential impacts of climate change are significant and the impacts of the 20 deployable output scenarios (see Section 3.13) vary greatly. From 2030 onwards over 50% of the Grid SWZ headroom allowance is due to the impact of climate change on supply. In our baseline scenario, the climate change impact is based on a scenario, that is close to the median if the outliers are discounted, and it

has a more sensible profile than the median (excluding outliers). The 20 climate change scenarios in the headroom component show by 2045 there is a 40% chance the climate change impacts could be less than predicted in the baseline scenario and a 60% chance they could be greater. This means there is a high risk of under or over investing in the risks of climate change. We therefore included a slightly more extreme climate change scenario in our dWRMP, see Section 9.7.

The most extreme climate change scenarios included in the headroom component represent a 10% chance loss of supply could be over 300Ml/d greater than the baseline scenario by 2045. At the beginning of the planning period the scenarios predict the impact of climate change could be up to 27Ml/d greater than the baseline scenario or 10Ml/d less. We have sufficient surplus (see Section 8.2) in the Grid SWZ baseline dry year annual average scenario to meet this early risk and our final planning scenario will improve our surplus. We will review the risk of climate change for future WRMPs to improve our understanding of the potential risks.

The most significant demand component of headroom is due to forecast variation in both zones. This is negative at the start of the planning period as there is a risk demand could be less than assumed in the baseline.

For the Grid SWZ, uncertainty due to gradual pollution also presents a significant risk. Although the risk of loss of supply does not change over the planning period it becomes less significant as climate change uncertainty increases.

7.3 Headroom assessment results

Table 7.4 shows the target headroom results using the selected percentile profile for each zone. For the East SWZ, we selected a profile with a percentile risk starting at the 95th percentile in the first five years of the planning period and decreasing in five percentiles with each five-year interval. This provides a target headroom allowance of nearly 8% of WAFU at the beginning of the planning period reducing to 5% by 2045.

We selected the 95th percentile at the beginning of the planning period to minimise the risks in the East SWZ, as this small zone has limited supply flexibility compared

to the Grid SWZ. A decreasing profile was selected as it is appropriate to accept a higher level of risk in the future than at present.

For the Grid SWZ, we have selected the 80th percentile risk at the beginning of the planning period, reducing to the 70th percentile in 2025 and the 55th percentile in 2030. We have then maintained headroom at this value for the remainder of the planning period. This provides a target headroom value around 5% of WAFU throughout the planning period.

We have selected a lower headroom risk profile for the Grid SWZ compared to the East SWZ, as a 95th percentile would be disproportionate to the risks. A 100% certainty assumes the worst-case scenario for each headroom component is realised in the same year, which is highly unlikely. It is most likely that the 50th percentile scenario would be realised.

Table 7.4 Target headroom using the probabilistic model

WRZ	Demand scenario	Target headroom allowance					
			2020/ 21	2025/ 26	2030/ 31	2035/ 36	2040/ 41	2044/ 45
East SWZ	Baseline dry year annual average	Certainty percentile	95th	90th	85th	80th	75th	70th
		Ml/d	0.94	0.83	0.79	0.71	0.67	0.62
		% of WAFU	7.7	6.8	6.5	5.8	5.5	5.1
Grid SWZ	Baseline dry year annual average	Certainty percentile	80th	70th	55th	-	-	-
		Ml/d	70.97	65.86	64.07	64.07	64.07	64.07
		% of WAFU	5.4	5.1	5.2	5.4	5.4	5.4

We need to avoid over investing in this zone, as the grid system allows us to manage loss of supply in the short term and future WRMPs will enable us to plan increased investment for the future if needed.

From 2025 onwards, a large proportion of the Grid SWZ target headroom is driven by climate change uncertainties, and the target headroom profile has been selected to reduce the level of risk planned for in the future at both a percentile uncertainty level and absolute value. We have chosen to do this as headroom uncertainty increases significantly after 2020 due to supply side climate change uncertainty.

In our options appraisal, we include a scenario to represent a higher climate change impact on supply than forecast in our baseline scenario. This allows us to test the solution against future climate change risks and reduces the need to account for climate change in the target headroom allowance. However, we have still allowed for some uncertainty due to climate change in the baseline scenario target headroom allowance. This takes a more precautionary approach than excluding climate change, without risking large investment in schemes that would be unnecessary if the worst case does not occur.

7.4 Reducing uncertainty

Our options for meeting any supply demand deficit are considered in Section 9. This includes identification of options that could reduce headroom uncertainties (Table 9.2). For this WRMP we have identified a number of options that could help mitigate risks due to pollution impacting on groundwater use in the Grid SWZ (component S5 Gradual pollution).

Our catchment management programme discussed in Section 3.16 will be our primary solution to mitigating pollution risks. However, we will consider the additional benefits of options that can help reduce headroom risks in our options appraisal.

Risks due to data accuracy and climate change cannot be reduced due to implementation of any specific options, but it is recognised that by reducing demand at a regional level we can reduce the risks to our level of service. In future WRMPs

our understanding of the impacts of climate change on water resources in our region may improve.

Demand variation (D2) is largely due to customer behaviour (PCC), population growth and new property development. These are beyond the control of Yorkshire Water and no options are included to reduce these uncertainties.

8 Baseline supply demand balance

Previous sections of our WRMP19 have described how we have developed baseline forecasts for supply and demand for each resource zone. Supply refers to the total water available for use. Demand refers to the sum of distribution input and target headroom.

This section shows how we have compared the supply forecast against the demand forecast to establish if we have sufficient supply to meet demand over 25 years. If the supply demand balance shows there is a deficit, we will need to invest in schemes to either increase supply or decrease demand to ensure we can meet our chosen level of service in the future.

8.1 East Surface Water Zone supply demand balance

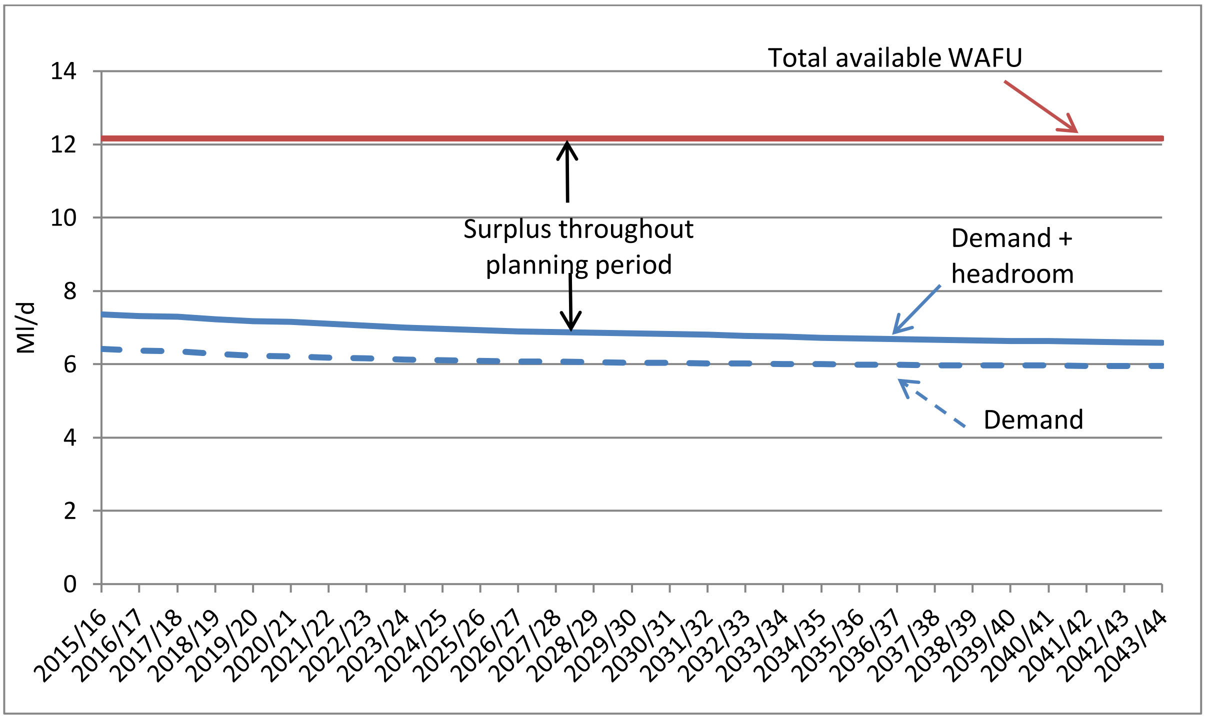
A supply demand appraisal has been undertaken for the East SWZ dry year annual average planning scenario. The forecast in this zone, as shown in Figure 8.1, is a surplus throughout the planning period.

Both supply and demand remain stable in the East SWZ baseline dry year annual average scenario. We have not identified any potential impacts on regional demand that would drive a deficit in this zone, nor any cross-sector demands that could be met through investment in the East SWZ.

There is a risk that climate change could impact on supply in the future, but the baseline dry year annual average scenario does not show a deficit in this zone. The East SWZ target headroom allowance includes uncertainty in the climate change forecast.

The supply surplus is 5Ml/d in 2020 and increases slightly over the planning period. This is nearly 50% of water available for use. As there is a large surplus, no investment is required to meet the levels of service in this zone over the 25-year planning period.

Figure 8.1 East SWZ baseline supply demand balance



8.2 Grid Surface Water Zone supply demand balance

The baseline supply demand balance for the Grid SWZ dry year annual average scenario is shown in Figure 8.2. This forecasts a risk the zone will be in deficit from 2035/36 onwards if we do not implement any supply or demand options.

The deficit is the result of a continuing decline in water supply, predominantly due to the risk of climate change impacting on available resources. Climate change is forecast to create a year on year incremental reduction in supply. Additionally, a 1.5Ml/d sustainability reduction is applied from 2023/24 onwards.

Demand does not change significantly over the planning period. Following an initial decline until 2025, it increases steadily over the remaining forecast period. The initial decline in demand is largely due to the planned additional 10Ml/d leakage reduction activity we will deliver before 2020 (as determined in WRMP14).

The Grid SWZ supply demand deficit in 2035/36 is 6.49Ml/d, increasing to 33.97Ml/d by 2044/45. The deficit is due to insufficient supply to meet the target headroom allowance. Supply is forecast to be above demand throughout the 25 years. A summary of the surplus / deficit is given in Table 8.1.

Figure 8.2 Grid SWZ baseline forecast supply demand balance

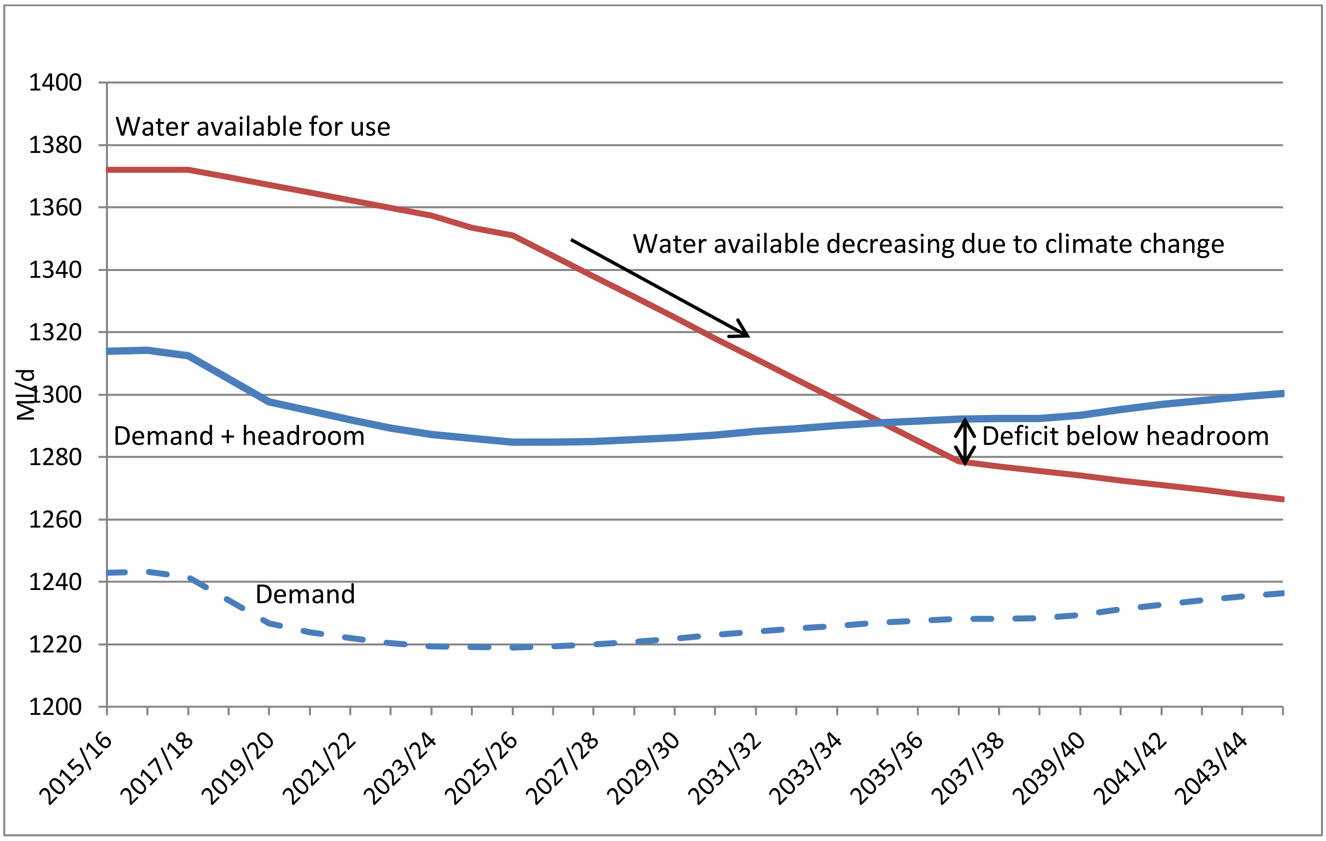


Table 8.1 Summary of the Grid SWZ supply demand deficit across the planning period

	2020/21	2025/26	2030/31	2035/36	2040/41	2044/45
Grid SWZ dry year annual average deficit (Ml/d)	+69.86	+66.19	+31.04	-6.49	-22.74	-33.97

9 Options appraisal

This section described the options we have considered to meet the Grid SWZ deficit and the process we have carried out to provide a solution to the deficit.

To close the deficit identified in the Grid SWZ, we need to invest in schemes that will either reduce future demand or provide additional supply. To select an appropriate solution to the deficit we consider all the options available and determine which are feasible. We then carry out an options appraisal to determine which of the feasible options provide the best value solution to the deficit over the long term.

The options appraisal aims to determine a solution that is sustainable against infrastructure limitations and future uncertainties, whilst minimising environmental impacts and meeting customers' preferences. We also incorporate government policy and regulatory requirements of Defra, Ofwat, Natural England and the Drinking Water Inspectorate into our decision making.

Infrastructure limitations on the feasible options are identified through our WRAPsim model. Environmental, customer and regulatory preferences are incorporated into our performance commitments, and we ensure our final solution to the deficit aligns with these commitments. Known future uncertainties can be considered through scenario or sensitivity testing. Unknown uncertainties are harder to plan for and often mean a flexible solution is preferred over the lowest cost solution.

9.1 Deciding on future options

Our options appraisal was carried out in accordance with:

- Final Water Resources Planning Guideline (Environment Agency, 2017);
- The economics of supply and demand (UKWIR, 2002);

- UKWIR WRMP 2019 methods - Decision Making Process: Guidance; and
- UKWIR WRMP 2019 methods - Risk Based Planning: Guidance.

In line with the UKWIR *WRMP 2019 methods - Decision Making Process: Guidance*, at the start of the planning process we carried out a problem characterisation assessment for our two water resource zones. This was based on our WRMP14 and any known changes since our last plan. The East SWZ baseline scenario is in surplus throughout the 25-year planning period therefore an options appraisal is not required.

As the Grid SWZ was forecast to be in deficit we used the problem characterisation assessment to review the possible methods we could use to determine the best solution. Our selected methodology is an aggregated approach with deterministic values of the supply and demand components over a 25-year planning period. This is the methodology defined in the *Economics of balancing supply and demand* (UKWIR, 2002) methodology.

We use a bespoke optimisation model known as WRIO (Water Resources Investment Optimiser) to determine the least cost solution. The lowest cost solution is derived from whole life costs, which include monetised costs for environmental impacts on recreation and tourism, social traffic interruptions and carbon emissions, as well as the economic costs.

The WRIO model includes interdependencies between options, such as prerequisites and mutual exclusions. Some resource options have non-linear impacts, wherein the option benefit is dependent on the deficit scenario and the potential implementation of other resource options. Any resource options selected in the least cost solution are assessed using our WRAPsim simulation model and this may lead to adjustments in yield benefits.

We then consider non-monetary factors in our decision making to determine the best value solution. These include customer and regulatory preferences, environmental and social impacts and resilience benefits of options. Environmental

and social non-monetised costs are determined through a Strategic Environmental Assessment (SEA), Habitats Regulation Assessment (HRA) and WFD assessment.

To take account of non-monetised factors we may decide to constrain out some of the feasible options or delay/bring forward certain schemes. We then re-run the optimisation model to provide a solution that is our preferred solution. This may take several iterations of the process.

The steps involved in moving from our least cost solution to our preferred solution to meet the Grid SWZ deficit are outlined below and summarised in

Figure 9.1.

9.1.1 Options appraisal process

Step 1. Collate an unconstrained list of options.

Step 2. Determine which of the unconstrained options are feasible options that have potential to meet the deficit in the Grid SWZ.

Step 3. Determine costs for each feasible option. This will include capital, operating, carbon, environmental and social costs.

Step 4. Carry out a SEA and HRA for each option.

Step 5. Input the 25-year supply demand balance and all feasible options and associated costs into WRIO.

Step 6. Run WRIO with all feasible options available to meet the deficit. This will provide an initial least cost solution to the deficit.

Step 7. Use our WRAPsim model to confirm the yield availability of any resource options selected as part of the least cost solution. This allows us to account for any non-linear options selected by WRIO modelling as part of the least cost solution.

Step 8. Re-run WRIO with option yields adjusted as determined in step 7. This provides the "final" least cost solution to the supply demand deficit. We may need to repeat steps 6 and 7 until an appropriate least cost solution is identified.

Step 9. Review the least cost solutions against the SEA outputs to determine which options would require delivery of mitigation measures environmental monitoring or, if the potential impacts are unacceptable, removal from the solution.

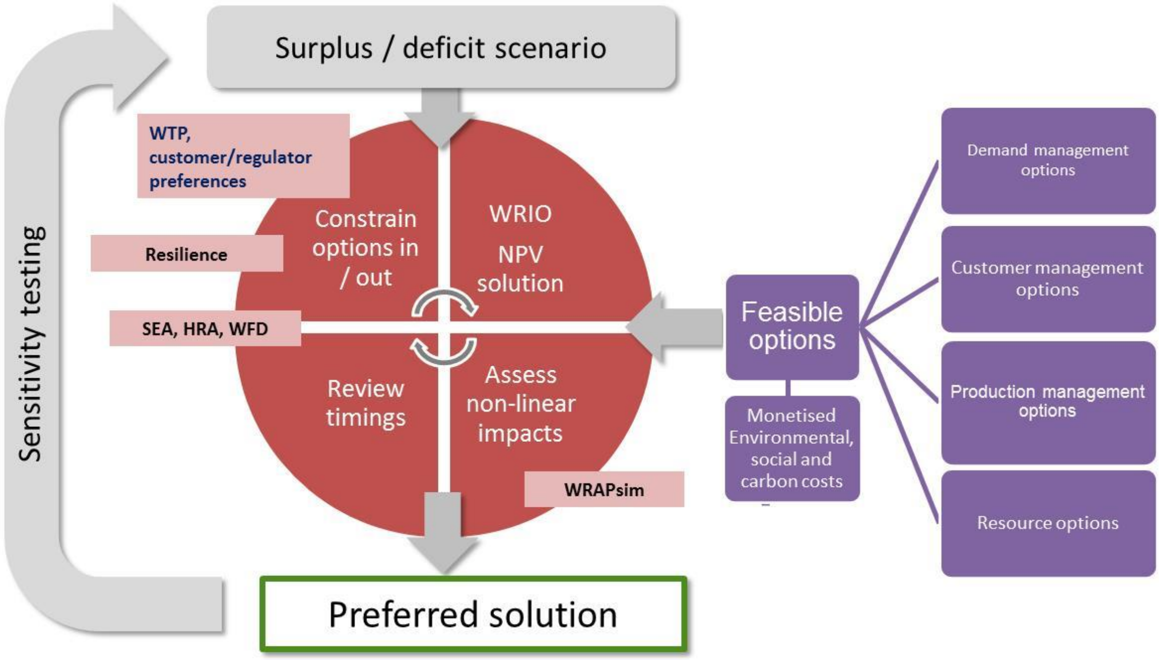
Step 10. Assess any additional benefits of the feasible options and if there are any drivers to "constrain in" specific options as part of the solution. For example, options which may:

- enhance resilience;
- meet the preferences of our customers, stakeholders and regulators;
- align with government policy;
- comply with our business objectives and PR19 performance commitments.

Step 11. Review our willingness to pay survey outputs and if this has any impact on the preferred solution, for example, are customers willing to pay for an increased level of service or willing to accept a reduced level of service.

Step 12. Re-run WRIO with the available options amended following steps 9 to 11. This may exclude some options entirely, delay or bring forward implementation of options or constrain in options to meet objectives in addition to the deficit. It may be necessary to repeat steps 5 to 11 until we determine the best value solution that balances potentially conflicting views while meeting our objectives.

Figure 9.1 Options appraisal process summary



9.1.2 Types of options available to meet the deficit

There are numerous options available to meet a supply demand deficit. They are grouped into four categories:

- **resource management** - options which increase deployable output;
- **production management** - options targeted at activities between abstraction and distribution input;
- **distribution management** - options targeted at activities between distribution input and the point of consumption; and
- **customer side management** - options to reduce customers' water use or supply pipe losses.

9.1.3 Development of potential options

For each WRMP we review the potential options available to meet a supply demand deficit and compile an "unconstrained" list of options. Unconstrained options include all options that could technically be used to meet the deficit. To compile the unconstrained list of options for this plan we carried out the following activities:

- reviewed the WRMP14 list of options to determine if they are still technically feasible;
- reviewed the options suggested in the *WR27 Water Resources Planning Tools,* UKWIR 2012 report;
- consulted third parties to review existing third-party options and identify new options; and
- consulted Yorkshire Water staff with knowledge of our supply system and operations, water production planning and service delivery.

To identify which of the options included in the unconstrained list should be investigated further we reviewed the technical, environmental, carbon and social attributes of each option at a high level. The technical attributes considered were yield increase/demand decrease; construction/delivery costs; time to implement; asset life of infrastructure; and resilience benefits.

This information was used to assess the schemes against the following criteria:

- Does the option address the problem?
- Does the option avoid breaching any unalterable constraints?
- Is the option promotable/does it meet regulatory and stakeholder expectations?
- Is the risk of the option failing acceptable?
- Should the option be taken through to the feasible list?

The answers to these questions were used to determine if the options were suitable to include in the options appraisal. This resulted in a sub-set of the unconstrained list of options, which is referred to as the "feasible" list. The unconstrained list, which is all the potential options we considered, is presented in Appendix A.1.

The feasible list is provided in Appendix A.2 with a brief description of each option. Details of the feasible options are provided in a supporting WRMP19 Options Technical Report, which was provided to the Environment Agency and made available on request.

9.1.4 Leakage options

For WRMP19 we have investigated the types of leakage reduction options available to us through further delivery of our existing leakage control measures and through identification of new measures, some of which we have started to implement in AMP6. The leakage options available for this WRMP are included in Appendix A.2. Our draft WRMP19 included a future leakage trajectory to achieve a 40% reduction by 2025. This was a seven- year plan starting in 2018/19. Since publishing our draft WRMP19 in September 2019 we have reviewed our progress in 2018/19 and reassessed the leakage options.

Our regulatory leakage target for 2018/19 was 292.1Ml/d and we out turned at 289.8Ml/d. This meant we met our regulatory target but did not achieve the draft WRMP19 target of 276Ml/d. During 2018 we experienced exceptional weather conditions that had a significant impact on leakage. Following on from the “Beast from the East” in February 2018, we experienced a period of hot and dry weather that led to a significant change in the Soil Moisture Deficit that was unprecedented in terms of both rate of change and deficit levels reached. This led to significant ground movement in many areas of our region, which resulted in increased leakage during the summer period.

Although Yorkshire Water had already committed significant additional resources to addressing leakage prior to the “Beast from the East”, we still experienced an increase in leakage against our planned trajectory during 2018 due to the summer breakout. Based on the outturn leakage of 2018/19 and our learning from implementing some of the new leakage options, we have reviewed the leakage trajectory and altered the 40% scenario. The updated 40% leakage scenario is provided in Section 9.7.4.

9.1.5 Resilience options

For WRMP19 we have considered vulnerabilities to future supply that are not addressed by meeting our planned level of service. Our outage assessment includes risks based on previous experience and provides an allowance for short term losses of supply. We have sufficient storage or alternative resources to ensure these outages do not impact on our levels of service.

There is a risk that extreme events cause one or more of our water treatment works or sources of supply to be out of supply or severely reduced for a prolonged period. To understand how resilient we are to these risks and where improvements can be made, our Asset Planning Team has carried out a preliminary assessment to

identify the water treatment works that are most vulnerable to extreme outage events.

Vulnerability was assessed by ranking them against a number of common hazards/threats, in line with the list of hazards presented in *Resilience planning: good practice guide* (UKWIR, 2013). In addition, we considered the performance of each works and likelihood of assets failing in the future.

The works identified as most vulnerable are in areas highlighted as being at increased risk of water supply failure due to reliance on single assets and/or sources of supply. We identified 10 principal threats that are a potential risk in our region, and these are presented in Table 9.1.

Table 9.1: Asset resilience principal threats

Hazard category	Principal threat
Weather and climate	Flooding
Pollution incidents	Extreme raw water quality / variability Extreme raw water pollution
Communication and power	Prolonged power outage Control system failure
Miscellaneous	Access loss for maintenance / supply chemicals
Asset performance	Failure of a process stage / component Failure of impounding reservoir Failure of raw water transmission system Failure of treated water transmission system

Current resilience of the sites was assessed by considering the ability to maintain supply through on-site storage and support from alternative water treatment works. Vulnerability was assessed against the number of properties that could be affected by extreme outage events.

The risks identified will be considered further in AMP7. A more detailed project will identify potential options and carry out investigations and a cost benefit assessment to provide a solution. This will be aligned with the options appraisals carried out in future WRMPs.

For WRMP19 the risk of pollution impacting on groundwater sources is included in our headroom assessment. We have an extensive catchment management programme that is being delivered in our region to reduce the risks of outages or loss of supply due to pollution in the future, see Section 3.14. Because of this, we will not be investing in any large resource schemes to mitigate these risks.

We have, however, considered which of the feasible options could provide resilience benefits through reducing outage and headroom risks, including potential for outages not previously experienced. This may lead to us prioritising some options above others if they can achieve multiple benefits, rather than investing in options that only address the level of service risk.

In addition to outage due to water quality we have considered risk of outage in areas where future housing developments are planned. North Yorkshire has been identified as an area of concern due to potential development in the area. We have sufficient resources to meet the demand but are potentially at risk if outages occur.

WINEP investigations will be carried out on a number of our groundwater sources with potential of leading to sustainability reductions. This will not lead to a reduction in deployable output, as there are conjunctive use systems where the licence capacity is greater than the source reliable output.

We have identified a risk in the East Yorkshire area of the Grid SWZ, where the combined impact of sustainability reductions and increasing nitrate and turbidity levels could create a greater risk of outages in this area.

A number of our resource options would provide alternative supplies to make our conjunctive use system more resilient to outage at water treatment works.

Some of our feasible WRMP options are also included in our Drought Plan as long-term drought options. We are currently resilient to a repeat of any previous droughts in our region and long-term drought options would only be required in an unprecedented event.

The most recent drought experienced in the Yorkshire region was in 2018, after our draft WRMP 2019 was submitted. We were able to maintain supply to customers throughout 2018, including during times of exceptionally high peak demand. However, we did cross a number of our Drought Plan triggers and we implemented drought actions including two drought permit applications.

The permits were granted by the Environment Agency and allowed an increase in the annual abstraction limits on two river sources. Both permits were “winter” permits and were valid between December 2018 and March 2019. The permits were applied for as a safeguard in case we experienced a prolonged period of increased winter demand that can result from bursts in our network due to pipes freezing at sub-zero temperatures then cracking when thawing. However, due to recovery in reservoir stocks and stable demand over the winter period, neither permit was implemented.

Although we had used the licences more than we would in a normal year due to high summer demands, we reserved sufficient spare licence capacity on the sources to ensure we could meet a period of high winter demand. However, there was a risk that we would have met the licence limits on the two river sources had we experienced an exceptional cold spell, such as the ‘Beast from the East’ in 2017.

We have provided the Environment Agency with a Lessons Identified report describing the 2018 drought impacts and outlining improvements for our Drought Plan. Neither of the drought permits we applied for in 2018 were options in our Drought Plan, which has since been revised to include the two river options and submitted to Defra.

The two drought permits we received permitted an increase to the annual average daily abstraction limits on river abstraction licences we hold on the River Wharfe and the River Derwent. In both cases we applied to increase the maximum annual abstraction volumes but did not alter the daily abstraction limits. This had minimal impact on the watercourses compared to 'normal' years as in most years the daily volumes would be available for us to abstract over the winter months. To provide drought/winter resilience to our supply network in the future, we have considered the potential to apply for the annual abstraction volume limits on both licences to be increased.

The River Derwent abstraction will be reviewed as part of a Habitats Directive Lower Derwent investigation, which means we would be unlikely to receive any additional annual licence volume. However, applying to the Environment Agency for an increase to the River Wharfe licence is a feasible option.

Table 9.2 provides the options that are included in our feasible options list and that would enhance grid links in our WRMP19, mitigate outage risks due to unknown sustainability reductions or are included in our Drought Plan as long-term drought options.

Table 9.2: Grid SWZ resilience options

Option reference and name	Resilience benefit
R1 River Ouse water treatment works extension R2 Ouse raw water transfer R5 Aquifer Storage and Recovery Scheme 1 R6 South Yorkshire Groundwater Option 1 R9 North Yorkshire Groundwater option 1 R12 East Yorkshire Groundwater Option 1 (link to grid system) R13 East Yorkshire Groundwater	Enhance conjunctive use in the Grid SWZ to make the zone more resilient to future headroom and outage risks such as; • Deteriorating water quality as a result of pesticide use. • New housing developments putting key WTW under stress if outages occur • Mitigate future sustainability reductions

Option reference and name	Resilience benefit
Option 2 R35 River Calder abstraction 1 or R37 River Aire abstraction 2 River Tees options (R49, R50, R51, R54 and R56)	
R1 River Ouse water treatment works extension R2 Ouse raw water transfer R9 North Yorkshire Groundwater option 1 R13 East Yorkshire Groundwater Option 2 R37 River Aire abstraction 2 R54 Tees to Ouse pipeline option 1	Included in the Drought Plan as potential long-term options
R72 River Wharfe licence increase	Improve Grid SWZ resilience to high winter demands following a dry summer when river abstractions will have been used extensively. The benefit of this option will only be in extreme years as the additional licence volume would not be utilised in a dry year scenario
Demand reduction options (production, customer and distribution management options)	Demand reduction could be focused in areas of the Grid SWZ where risks of future outages have been identified

9.1.6 Third party options

When compiling our list of potential options, we consult with third parties who could provide potential solutions. Third party options can include upstream services such as the provision of water, leakage detection and demand management. For WRMP19 we have engaged with our neighbouring water companies and other third parties including the Coal Authority and the Canal and Rivers Trust.

Neighbouring water company options

During the pre-consultation phase we met with our neighbouring water companies - Northumbrian Water, United Utilities, Severn Trent Water and Anglian Water - to discuss potential water trading opportunities. These discussions included both the import and export of water.

Our discussion with Northumbrian Water identified options to import water from the River Tees, with variations on how the water could be transferred. There are no options available for us to export water to Northumbrian Water.

We include three options for importing water from Northumbrian Water. These include an option to transfer raw water from a Northumbrian Water abstraction point on the River Tees to the Yorkshire Dales supply area, where a new treatment works would be constructed. As an alternative to this we include an option to import treated water from Northumbrian Water to the Yorkshire Dales. Both these options have potential to provide 15Ml/d additional resource to the Grid SWZ.

Our third option to import from Northumbrian Water is a raw water transfer from the River Tees to an existing water treatment works in the York area. This would require construction of a new pipeline. The option could provide up to 140Ml/d and is the largest of our feasible options. The option is divided into three phases of increasing volume, as it may be more cost efficient to transfer a lower volume. The first phase provides 50Mld and is the maximum spare licence capacity Northumbrian Water could provide as a transfer.

Phases 2 and 3 would require additional licence permissions from the Environment Agency for volumes greater than 50Ml/d. They would also require a new pump and electricity supply to be installed to transfer water from Kielder to the River Tees.

Our discussions with Northumbrian Water for this plan confirmed it has potential to provide a transfer, but the terms and the exact volume would need to be determined through a bulk transfer agreement, with Yorkshire Water funding any additional infrastructure requirements.

Our meeting with United Utilities identified two confirmed options for an import from United Utilities. We previously included an export from Yorkshire Water to United Utilities via the Huddersfield Canal. Discussions with the Canal and Rivers Trust for this plan identified that they may potentially require the water from United Utilities themselves and would not be able to agree the transfer to Yorkshire Water.

The two United Utilities imports included in our feasible options are both for a 1Ml/d volume. One option would connect an existing raw water pipeline to deliver water to the North Yorkshire area of the Grid SWZ. The other would involve installing a clean water pipeline, also to provide supply to North Yorkshire.

Discussions with Severn Trent Water identified one export and no import options. Our export would transfer up to 20Ml/d of treated water from South Yorkshire to Severn Trent Water via a new pipeline.

Discussions with Anglian Water did not identify any imports or exports for WRMP19 but did open discussions on a potential shared resource development that may become feasible in future WRMPs.

An outline of all feasible imports and exports is provided in Appendix B. We have not identified a bulk transfer as part of our preferred solution and Severn Trent Water does not require a transfer from Yorkshire Water.

Water Resources North – co-ordinating across the north to support national resilience

Recognising that we have a role to play in supporting not only the resilience of our region, but also the resilience of the UK, we have taken a lead in setting up Water Resources North. This group, which comprises representation from across water companies in the north of England as well as key regulators, will provide a focal point for co-ordinating water resources across the north and will also help us to ensure that the emerging national water resources framework is support from our region, and is reflected in our future plans. Further, it will allow for integrated and consistent consideration of the opportunities that, collectively, northern water companies may have to transfer water to other parts of the country and contribute to enhanced national water resilience.

Other third-party options

We have met with the Coal Authority and the Canal & River Trust to discuss third party licence trading. There were no Canal & River Trust options developed from these discussions.

The Coal Authority proposed several mine water discharges in our region and provided water quality data. We selected two of the sites for further investigation, however the options were constrained out due to risks the water could not be treated to the correct standard for potable water supply. Although it was noted that transferring the supply via reservoirs could provide some dilution to mitigate the risks.

We have published water resources market information on our website alongside our WRMP19, using a data template provided by Ofwat. This will enable third parties to identify opportunities to provide new water resources and demand management and leakage services. For Yorkshire Water, this will allow us to engage further with third parties and encourage development of potential options.

9.1.7 Water market

We recognise that the use of third-party options and a water resource market could help us deliver resilience, cost efficiency and innovations.

We are therefore currently encouraging a water bidding market and plan to stimulate this market through early engagement with potential participants and have created a dedicated water bidding market page on the Yorkshire Water website www.yorkshirewater.com/about-us/what-we-do/become-a-supplier-of-yorkshire-water/water-bidding-market/.

We have met with a specialist licence trading consultant to understand available water resources and potential opportunities for our region. We also plan to help strengthen and protect national resilience in the longer term by understanding the need for and approach to transporting water around our country. This will be facilitated through the Water Resources North group.

As part of our initiative to explore the water resources market, we have developed a geographic information system (GIS) tool which shows all third-party and our own abstraction points in Yorkshire. This tool makes potential trades more visible and helps us to identify locations where we may be able to optimise the use of existing third-party water abstraction licences.

We will pursue trades where they make us more efficient or resilient, meeting the needs of our customers, stakeholders and the environment.

Our aim is to improve regional and national resilience, reduce waste and support innovation through three initiatives: pursue increased trading to deliver efficiency and reduce the need for capital expenditure; utilise experts to introduce improved approaches and technology; and, collaborate to do more than we could alone.

Our Water Bidding Market webpage will list all opportunities for the water management market, including water resources, demand management and leakage services. The webpage allows us to share trade opportunities quicker than the published Market Information requirements as it will enable:

- Communication between us and other water companies or third parties, including the ability to submit bids;
- Engagement with the market when we want to understand potential solutions before starting procurement (market testing); and,
- A route for the market to submit prospective solutions unrelated to a specified requirement.

The webpage is supported by our Trading and Procurement Code, Bid Assessment Framework and a proportional procurement process. We are currently investigating any perceived barriers to entry.

Developing the market

We are reaching out to participants to stimulate interest, and our published Market Information is the first step in this process. We have also asked third parties to tell us what other market information they need to help us drive resilience, innovation and efficiency into water resources. All market participants will be able to review and comment on our approach and systems before we go live.

Bilateral trading market

We are reaching out to participants to stimulate interest, and our published Market Information is the first step in this process. We have also asked third parties to tell us what other market information they need to help us drive resilience, innovation and efficiency into water resources. All market participants will be able to review and comment on our approach and systems before we go live.

9.1.8 Option costing

We calculated build costs and operating costs for each feasible option, as presented in Table 5 of the water resource planning tables. For most new resource and production schemes the cost components for construction were provided by our unit cost database. The unit cost data base provides costs for capital components based on previous schemes we have delivered.

Options that have not been developed in our region previously, such as desalination, are based on a desk study and inflated to today's prices. Our experience of delivering schemes provided the costs data for a number of the distribution and customer management options. We used desk-based research studies to cost options where new techniques would be delivered.

9.1.9 Environmental, social and carbon costs

We have considered the monetised and non-monetised costs of the environmental, social and carbon impacts of the feasible options in our options appraisal. The non-monetised environmental and social impacts are determined in a Strategic Environmental Assessment, as described in Section 9.3.

We assessed carbon, environmental and social monetised costs for all feasible options through a desk-based study. Costs for new schemes were calculated and costs for schemes included in WRMP14 were reappraised.

The *Environmental Valuation in Water Resources Planning - Additional Information* (Environment Agency, 2016) recommends the use of a risk-based approach to assessment of environmental and social impacts of the plans. This allows water companies to implement a proportional level of effort when assessing the

externalities (i.e. unintended environmental, including carbon emissions, and social impacts) of the plan, and not be required to monetise all impacts.

For the environmental impacts, the Environment Agency encourages the use of the ecosystem services approach as a first step in assessing the WRMPs, although it also presents alternative appraisal methodologies. For WRMP19, we identified environmental impacts using the ecosystem services approach and were also informed by results of the Strategic Environmental Assessment.

The monetisation of impacts focused on the ecosystem service of recreation and tourism. The rationale for this, the method applied, and data used to calculate and monetise the value of the impacts are further explained in an Environmental Economics Technical Report which has been provided to the Environment Agency and is available upon request.

The embedded (capital) carbon impacts, measured in tCO2e (tonnes of carbon dioxide emissions), were assessed following the recommendations of the guidance *A Framework for Accounting for Embodied Carbon in Water Industry Assets* (UKWIR, 2012). Whereas, operational carbon impacts measured in tCO2e emissions, were estimated using a Yorkshire Water specific methodology (Turner and Townsend, 2016).

Capital carbon impacts were monetised using the traded cost of carbon, while the operational carbon impacts were monetised using both the traded and non-traded cost of carbon, depending on whether the operational input is or is not in scope of the EU Emissions Trading Scheme (EU ETS).

The only social impacts considered are traffic related costs due to the construction work for WRMP options. Social costs in relation to traffic were developed in a Yorkshire specific study, *Lane Rental Charging – A Way Forward* (Stone and Webster, 2002). This was used for the calculation of traffic costs of the relevant WRMP19 options, and further information on the methodology and other data used can be found in the technical report.

The environmental, social and carbon monetised costs and benefits are included in Table 5 of the water resource planning tables.

9.2 Determining the solution

Once we have collated our feasible list of options and calculated the costs we input the data into our WRIO optimisation model. The costs and benefits for each feasible option are calculated in accordance with Section 6.7 of the *Final Water Resources Planning Guideline (*Environment Agency, 2017).

The WRIO model inputs include the following data for each individual option and further information is provided in Appendix B:

- yield benefit as a supply increase or a demand reduction;
- yield ramp up – percentage yield available each year until achieve 100%;
- first feasible year of operation – allow for investigations and construction;
- build and replacement capital costs divided into civil, instrumentation and automation (ICA), land and mechanical and electrical (M&E);
- environmental, social and carbon capital (build) costs;
- fixed and variable operating costs and benefits, including environmental, social and carbon;
- build profile – percentage of capital cost invested each year before and after the first year of utilisation;
- prerequisite option – link to another option that must be selected before the option can be in use and the "lag" time between implementation; and
- mutual exclusions / option dependencies – option selection is dependent on the selection of another option(s), for example, we may have more than one option available to utilise an individual river or groundwater resource but can only utilise one of the potential schemes.

The WRIO model uses the above cost / benefit information for individual options to identify the least cost solution that ensures supply can meet demand plus target

headroom for each year of the 25-year planning period. It optimally schedules investment to meet the projected deficit at minimum net present cost (NPC). It can also provide a solution to a 40-year planning period.

The WRIO model utilises a linear/integer programming approach, as described in the report, *The Economics of Balancing Supply and Demand* (Environment Agency and UKWIR, 2002).

The integer programme technique selects a schedule of options that will, in aggregate, meet any projected deficit in each year, from the base year to the end of the 25-year planning horizon. The selected schedule of options has the least net present value (NPV).

The output from the model includes average incremental cost (AIC), average incremental social cost (AISC) and net present value (NPV), as defined in *The Economics of Balancing Supply and Demand* report, based on the output of the scheme.

Costs and benefits are discounted over a 100-year period as this is the lifetime of the longest lasting asset. The model bases discount rates and net present value calculations on the criteria specified in the *Water Resources Planning Guideline* (Environment Agency and Natural Resources Wales, 2017). For each feasible option, it calculates the profile of the costs over 100 years, split into capital (including maintenance and replacement costs); operating (both fixed and variable costs) and financing costs.

Financing costs are calculated as a stream of annual costs over the life of the option, using an assumed 3.6% average cost of capital (the "vanilla" real wholesale weighted average cost of capital (WACC) in PR14). The NPV of all costs is then calculated using the *Treasury Test Discount rate* as set out in the *HM Treasury "Green Book"* (Appraisal and Evaluation in Central Government, HM Treasury, 2003). This is 3.5% for years 0 to 30 of the appraisal period, 3.0% for years 31 to 75, and 2.5% for years 76 to125.

WRIO produces AICs and AISCs for all options using their first feasible implementation year (as shown in Table 5 of the water resources planning tables).

9.2.1 WRAPsim modelling of options

To cost the schemes for the Grid SWZ, each feasible supply side option is assigned a yield that could be available from implementing the individual scheme. However, the final yield of each scheme is influenced by the supply demand balance scenario and the other options selected. WRAPsim modelling is used to determine the option yield, taking into account the hydrological conditions and infrastructure constraints of the Grid SWZ at the given deficit.

We cannot confirm the option yield in WRAPsim until after the supply demand deficit is known. For example, the River Ouse Raw Water Transfer option has a maximum capacity of 60Ml/d, but the amount taken will depend on the available treatment capacity at the receiving water treatment works. We cannot take 60Ml/d if the water treatment works does not have this spare capacity. However, we cannot determine the yield the option can provide until the impacts of climate change and sustainability reductions are known, as these factors will impact on the volume of water available to treat at the treatment works.

WRAPsim also needs to consider the cumulative impact of the options selected. The yield of the scheme may be dependent on the other schemes selected, particularly if the yields are to be treated at the same treatment works.

An initial run of the optimisation model with the schemes at their maximum capacity provides an initial solution to the deficit. Any resource schemes selected are then considered in WRAPsim to determine how much of the maximum yield could be used in the dry year annual average scenario. The schemes are considered in WRAPsim in correlation with each other to account for any interdependencies. The yields of options in the optimisation model are then revised to include any reductions due to hydrological and infrastructure constraints. This stage is only required if the initial optimisation run selects resource schemes with uncertain yields.

9.2.2 Impact of climate change on options

None of our options have been found to be directly affected by climate change. The options in our preferred solution have been modelled with our selected climate

change scenario to ensure that the options are robust to climate change. This is fully described in the Climate Change and Deployable Output Technical Report.

9.3 Strategic Environmental Assessment, Habitats Regulation Assessment and Water Framework Directive

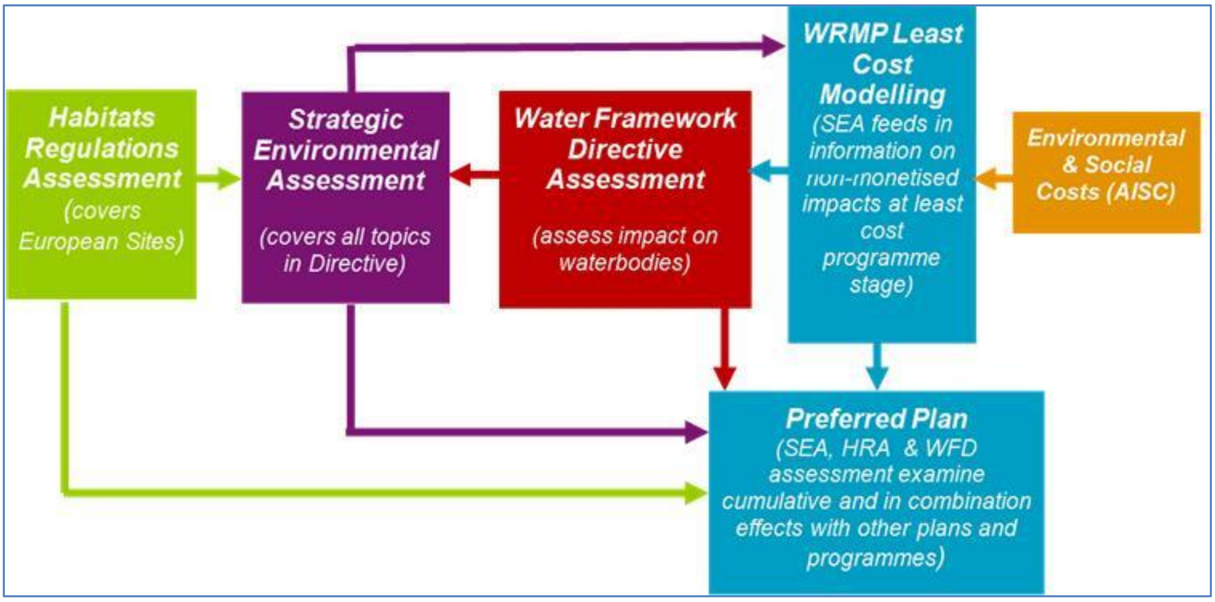
The non-monetised environmental, social and carbon impacts of each option have been considered in a Strategic Environmental Assessment (SEA). The full output of the SEA is provided in an Environmental Report, which is published on our website alongside this document.

We have reviewed all available guidance; Strategic Environmental Assessment and Habitats Regulation Assessment Directive (UKWIR, 2012) and A Practical Guide to the Strategic Environmental Assessment (ODPM, 2005), and determined that the WRMP falls under the SEA. Notably, this is because the WRMP will include schemes that will required an Environmental Impact Assessment (EIA).

The SEA and the WRMP options appraisal have been informed by a Habitats Regulations Assessment (HRA) Screening Report. The *Water Resources Planning Guideline* (Environment Agency and Natural Resources Wales, 2017) also recommends water companies include the net impacts of the solution on waterbody status under the WFD in the environmental and social assessment. A WFD Assessment has therefore been carried out to inform the SEA and assess the impact of the least-cost plan on WFD requirements for no deterioration to waterbodies. The findings of the HRA and WFD assessments were submitted to the relevant regulators (Environment Agency and Natural England, where relevant) for consultation during July and August 2017. The HRA and WFD compliance assessment reports were also submitted to these regulators at the time of publishing the draft WRMP19, although these have subsequently been updated to include further work post-consultation.

The SEA, HRA and WFD assessments are used in the options appraisal to help determine a preferred solution that reduces the risk of detrimental impact to the environment. Figure 9.2 outlines the process for integrating the SEA, HRA and WFD into the options appraisal.

Figure 9.2 Integration of SEA, HRA and WFD in the WRMP Process



The SEA can add value to the options appraisal process by identifying a wider range of impacts that cannot be monetised. It considers both adverse and beneficial potential environmental and social effects of feasible options and identifies the cumulative effects of a supply demand solution.

A cumulative, or in-combination, assessment has been undertaken on the preferred solution. This involved examining the potential impacts of each of the water resources management options in combination with each other, as well as in combination with the implementation of other relevant plans and programmes.

We have ensured the environmental and social impacts are not double counted in both the monetisation process and the SEA, as this could potentially skew the options and programme appraisal process.

The overall findings of the SEA describe the extent to which objectives for eight environmental topics are met by each of the WRMP options. Table 9.3 lists the topics and associated objectives.

Table 9.3 SEA topics and objectives

SEA Topic	Ref.	SEA Objectives
Biodiversity, flora and fauna	1.1	To protect and enhance biodiversity, ecological functions, capacity, and habitat connectivity within Yorkshire Water's supply and source area.
	1.2	To protect, conserve and enhance natural capital and the ecosystem services from natural capital that contribute to the economy.
	1.3	To avoid introducing or spreading INNS.
Population and human health	2.1	To protect and improve health and well-being and promote sustainable socio-economic development through provision of access to a resilient, high quality, sustainable and affordable supply of water over the long term.
	2.2	To protect and enhance the water environment for other users, including recreation, tourism and navigation.
Material assets and resource use	3.1	To reduce, and make more efficient, the domestic, industrial and commercial consumption of resources, minimise the generation of waste, encourage its re-use and eliminate waste sent to landfill.
Water	4.1	To maintain or improve the quality of rivers, lakes, groundwater, estuarine and coastal waterbodies.
	4.2	To avoid adverse impact on surface and groundwater levels and flows and ensure sustainable management of abstractions.
	4.3	To reduce and manage flood risk.
	4.4	To increase awareness of water sustainability and efficient use of water.
Soil, geology and land use	5.1	To protect and enhance geology, geomorphology, and the quality and quantity of soils.
Air and climate	6.1	To maintain and improve air quality.
	6.2	To minimise greenhouse gas emissions.
	6.3	To adapt and improve resilience to the threats of climate change.

SEA Topic	Ref.	SEA Objectives
Archaeology and cultural heritage	7.1	To conserve and enhance the historic environment, heritage assets and their settings and protect archaeologically important sites.
Landscape and visual amenity	8.1	To protect and enhance designated and undesignated landscapes, townscapes and the countryside.

A ten-point impact assessment scale was used, using the effect categories: major adverse; moderate adverse, minor adverse; negligible adverse; no adverse effect, no beneficial effect, negligible beneficial, minor beneficial; moderate beneficial and major beneficial. This report considers the outputs of the SEA on the least cost solution and the preferred solution. The SEA outputs for all the feasible options can be found in the SEA Environmental Report.

9.4 Customer views on options

For WRMP14 we carried out research into customer preference and prioritisation of the different investment options available.

A two-stage approach using qualitative and quantitative research was used. An exploratory, qualitative phase was used to refine the options to ensure they were understood by customers, and the quantitative phase was used to establish which options consumers preferred.

Customers were asked to rate a range of potential options before and after being provided with information on the cost, environmental impact and security of the yield for each option.

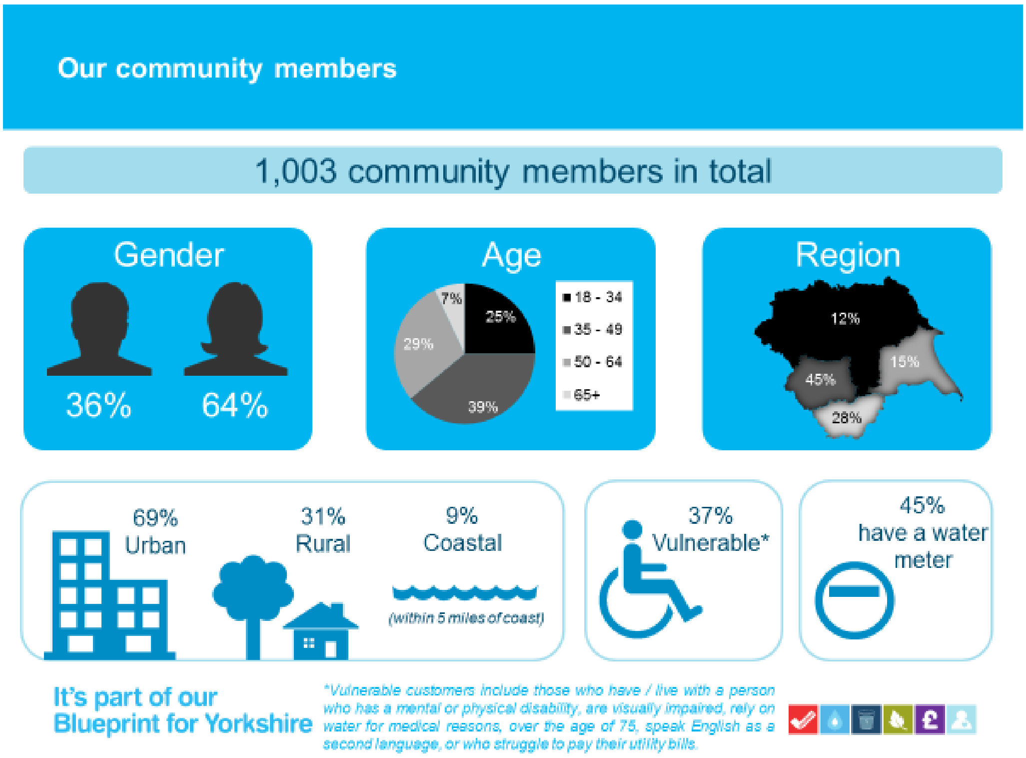
Initially customers' preference was for mains replacement and leakage reduction. Priority was also given to schemes such as reservoir de-silting, water efficiency and supply pipe renewal. When provided with cost, environmental impact and yield security information, preference was for leakage reduction, metering and water mains replacement.

In both the qualitative and quantitative research preference was towards options that saved water. Options that increase available supply were less attractive to customers due to a perceived negative environmental impact.

This research was carried out in the last five years, so the information is considered to remain valid and useful for water resource planning. However, to supplement this for WRMP19 we have repeated this research with our online community 'Your Water' to refresh our understanding of customers' priorities around water use and investment options.

'Your Water' is an independent customer online community, run by a market research specialist. It was set up in January 2017 to generate an informed customer view of Yorkshire Water and the service we provide, looking wider than general consumer understanding of providing fresh clean water and removing waste. For business planning for WRMP19 and PR19 the community represent the voice of the informed customer, as they have a better understanding of our business allowing them to offer more guidance and direction on what is best for Yorkshire Water and what is best to meet the needs of our wider customer base.

Figure 9.3 Our online community membership



This online community also allows consultation with customers on specific areas, ensuring we are delivering what our customers want and need. For example, we have consulted on topics such as: customers' financial outlook, testing the look and feel of our brand and marketing materials, the design and readability of our bills and how we engage with local communities when we are implementing a disruptive improvement scheme.

Figure 9.3 below outlines the breakdown of customers on our online community. Except for gender (females are more likely to sign up to online communities), the breakdown of community members is representative of our region in terms of age profile, location and vulnerability.

Customers were presented with 15 potential 'high level' options for managing future water supply including a range of demand management, resource management and distribution management schemes. Customers were asked to rate each potential idea (on a scale from very good idea to very bad idea) and then asked to decide which three options they consider to the best ideas for managing future water supplies. The results of this are presented in figures 9.4 and 9.5 below.

Figure 9.4 Customer rating of potential options

Figure 9.5 Customers preferred options for managing future water supplies

Top rated NET good ideas	NET good idea	% best ideas
Water mains renewal	97%	24%
Leakage reduction	93%	56%
Supply pipe leak reduction	88%	35%
Reservoir Desilting	84%	25%
Customer water efficiency (Homes and Businesses)	78%	21%
Smart water meter	67%	26%
Compulsory metering	61%	25%

Water mains renewal and leakage reduction were preferred options for managing the future water supply. Importing water from other companies received relatively little support.

Customers were then presented with additional information about each option including the relative cost, environmental impact (both negative and positive) and confidence around the water delivered or water saved for each scheme. Then were then asked again for their top three preferences and to give their reason.

This information did not change customers' preferred options, with cost and environmental impact information reinforcing their decision. Customers' top three preferred options based on all the information provided are shown in Figure 9.6 below.

Figure 9.6 Customer top three preferred options

68%	36%	30%
Leakage reduction	Supply pipe leak reduction	Water mains renewal

9.5 Grid Surface Water Zone least cost solution

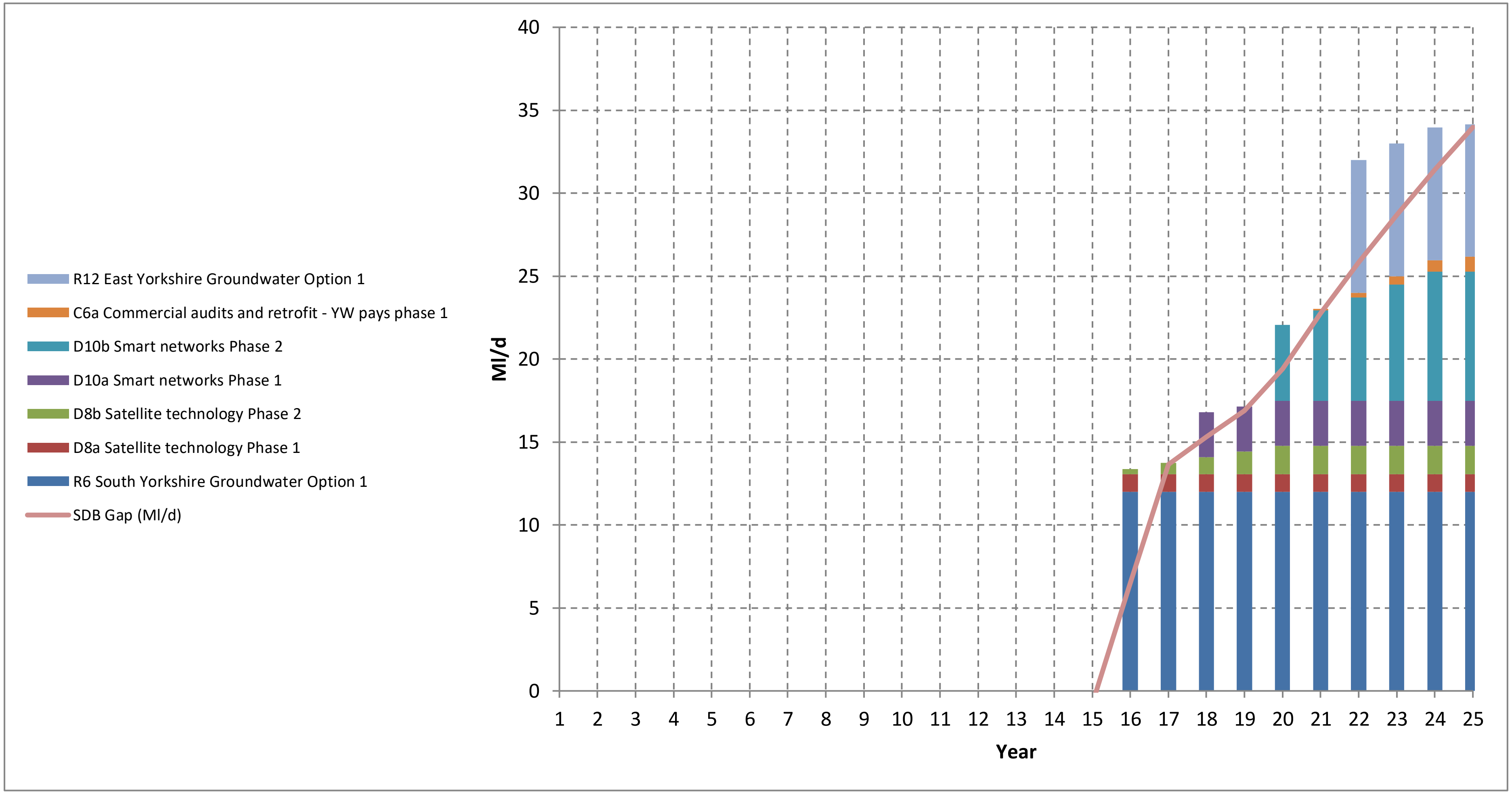
The WRIO optimisation model was used to determine the least cost solution for meeting the deficit identified in the Grid SWZ baseline dry year annual average scenario described in Section 8.2. The planning period for the baseline scenario is 25 years from 2020/21 to 2044/45. The WRIO output for the baseline scenario is shown in Figure 9.7

The least cost solution includes seven options; five distribution management options that reduce demand for water and two resource options that increase supply availability. The options will be implemented from year 16 (2035/36) onwards. The distribution management options contribute 41% of the total solution, will achieve 13.26Ml/d in additional leakage reduction and deliver 0.9Ml/d of water efficiency activity to commercial water users. By the end of the 25-year planning period the least cost solution will reduce leakage to 273.8Ml/d, a 5% reduction compared to the current leakage target of 287.1Ml/d in 2019/20.

The two resource options make up 59% of the solution and provide a total of 20Ml/d in additional supply. The first supply side option would be implemented in 2035/36 (year 16 of the planning period) and is a new connection from a group of groundwater licences in South Yorkshire (R6 South Yorkshire Groundwater Option 1) that provides an additional 12Ml/d resource. The second supply side option would be implemented in 2041/42 (year 22) and provide an additional 8Ml/d from a borehole group in East Yorkshire (R12 East Yorkshire Groundwater option 1).

R6 South Yorkshire Groundwater Option 1 and R12 East Yorkshire Groundwater Option 1 will utilise existing licence capacity through investment in new infrastructure to enhance the grid system. In addition to the supply side benefits resource options R6 and R12 have potential to provide resilience by improving connectivity in the Grid SWZ. This will increase our ability to move water around the region to meet peak demands and provide alternative resources when outages occur.

Figure 9.7 Grid SWZ baseline scenario least cost solution



However, the licences are included in WINEP investigations and there is a risk the yield benefit could reduce if sustainability reductions are applied to these licence groups. WINEP investigations will be carried out by 2022 to determine the impact on our current licence permissions. The uncertainty over these options would be resolved by the time we were required to implement either option, but this does pose a risk to the delivery of the least cost solution.

9.6 SEA of least cost solution

Table 9.3 provides a summary of the SEA outputs for the least cost solution. Most impacts are negligible, but there are several minor adverse and minor beneficial impacts. There is one solution that has a moderate adverse impact in relation to one SEA objective (R6 South Yorkshire Groundwater Option 1).

The R6 South Yorkshire Groundwater Option 1 solution is present in the least cost solution from our plan. However, this scheme is in WINEP and, although abstraction would be within existing licence conditions, there is a risk of potential deterioration between classes, and potential flow reduction impacts on dependent surface water body status.

The R12 East Yorkshire Groundwater Option 1 is also present in the least cost solution. This is also a WINEP scheme and although the licensed limit is underutilised there is a risk to future abstractions due to potential saline intrusions.

For both schemes, further investigations would need to be carried out to confirm these impacts before we could be confident the schemes could be implemented.

We have also reviewed the SEA results of all the selected options to consider the actions we can take to mitigate the environmental and social impacts. It is not always practical to constrain out all schemes where there are potential negative impacts, as the remaining schemes may not meet the deficit and the cost could be disproportionately high. Our preference is to constrain out options classified in the SEA as having a major adverse impact on the environment. This includes reservoir desilting, desalination and the Tees to Ouse options. However, if these options were selected as part of the solution, we would consider the wider benefits of the schemes and how we might mitigate the impacts before constraining out.

If the SEA highlights an adverse impact that is not classed as major adverse but presents an impact that is disproportionate to the yield gain or a risk that could increase in the future, we would consider constraining out the option.

The remaining options within the least cost solutions do not raise any moderate or major adverse impacts. Most minor adverse impacts relating to the distribution management and customer management options are temporary and relate predominantly to the intermittent increases in vehicle movements associated with each scheme and the potential temporary health effects associated with dust, noise and vibration from installation of equipment on public rights of way and roads. The minor and major beneficial effects identified are in relation to sustainable and efficient use of water resources. Water savings brought by these options would support population health and economic development and improve climate change resilience.

Table 9.3 SEA outputs of Grid SWZ least cost solution

Adverse

Option Category	Scheme Ref.	Scheme Name	Biodiversity, flora and fauna 1.1	1.2	1.3	Population and human health 2.1	2.2	Material assets and resource use 3.1	Water 4.1	4.2	4.3	4.4	Soil, geology and land 5.1	Air and climate 6.1	6.2	6.3	Archaeology and cultural heritage 7.1	Landscape and visual 8.1
Customer management	C6a	Commercial water user audits and retrofit (phase 1)	N	N	N	N	N	N	N	N	N	N	N	-	-	N	N	N
Distribution management	D8a-b	Satellite Techology	N	N	N	-	N	-	N	N	N	N	N	-	-	N	N	N
Distribution management	D10a-b	Smart Networks	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Groundwater	R6	R6 South Yorkshire Groundwater	N	N	N	-	N	-	-	--	N	N	-	N	-	N	N	-
Groundwater	R12	R12 East Yorkshire Groundwater Option 1	-	N	N	-	N	-	-	-	N	N	N	-	-	N	N	-

Beneficial

Scheme Ref.	Biodiversity, flora and fauna 1.1	1.2	1.3	Population and human health 2.1	2.2	Material assets and resource use 3.1	Water 4.1	4.2	4.3	4.4	Soil, geology and land use 5.1	Air and climate 6.1	6.2	6.3	Archaeology and cultural 7.1	Landscape and visual amenity 8.1
C6a	+	+	N	+	N	+	N	+	N	+	N	N	N	+	N	N
D8a-b	+	+	N	+	N	+	N	+	N	+	N	N	N	+	N	N
D10a-b	+	+	N	++	N	++	N	+	N	+	N	N	N	++	N	N
R6	N	N	N	+	N	+	N	N	N	N	N	N	N	+	N	N
R12	N	N	N	+	N	N	N	N	N	N	N	N	N	+	N	N

---	M
--	M
-	M
N	N
None A	N
None B	N
N	N
+	M
++	M
+++	M

9.7 Grid Surface Water Zone sensitivity testing

The deficit presented in our baseline scenario is driven by a risk that hotter and drier summers will reduce water availability in the future. It is not possible to accurately predict how severe the impact will be. We have modelled 23 climate change scenarios impacting on supply, as described in Section 3.11, and selected a scenario to represent the risk of climate change reducing supply in our baseline dry year annual average scenario.

There is a risk that we have underestimated the impact of climate change on future supply availability in the baseline scenario, and the reduction in water available for use may decline at a much steeper rate. This would require greater intervention than required in the baseline scenario. Climate change is likely to continue to impact on water availability beyond the 25-year planning period and this may lead to an alternative solution being selected.

Alternatively, climate change could be less severe than predicted in the baseline scenario and we want to be confident our plan is resilient to an uncertain future.

To ensure there is no risk to future security of supply it is important that we consider alternative future scenarios that allow for uncertainty not evident in the headroom assessment. We have also developed a number of new leakage techniques and have created scenarios to increase our leakage activity beyond our current target. In total, we have considered five supply-demand balance scenarios, all representing the dry year annual average:

Scenario 1: Baseline dry year annual average: 25-year forecast, leakage activity maintaining the 2019/20 287Ml/d target, climate change based on model ID 7910.

Scenario 2: More extreme climate change: 25-year forecast, leakage activity maintaining the 2019/20 287Ml/d target, climate change based on the median scenario excluding outliers, model ID 9500.

Scenario 3: Baseline extended to a 40-year period: 40-year forecast, leakage activity maintaining the 2019/20 287Ml/d target, climate change based on model ID 7910.

Scenario 4: Baseline plus a 15% leakage reduction: 25-year forecast, leakage activity reducing leakage to a lower 244Ml/d target by 2025, climate change based on model ID 7910.

Scenario 5: Baseline plus a 40% leakage reduction: 25-year forecast, leakage activity reducing leakage each year of the planning period to ensure a 40% reduction from the baseline regional leakage target by AMP9. This includes an initial 9% reduction in 2019/20 from 287Ml/d to 269Ml/d. A further 25% leakage reduction is delivered during AMP7. By year 3 (2032/33) of AMP9 our regional target is reduced to 176Ml/d, this will be a 40% reduction against our baseline regional target of 297.1Ml/d. Leakage reduction activity continues to the end of the planning period to meet a target of 150Ml/d by 2045. Climate change based on model ID 7910.

Figure 9.8 Grid SWZ supply demand balance scenarios

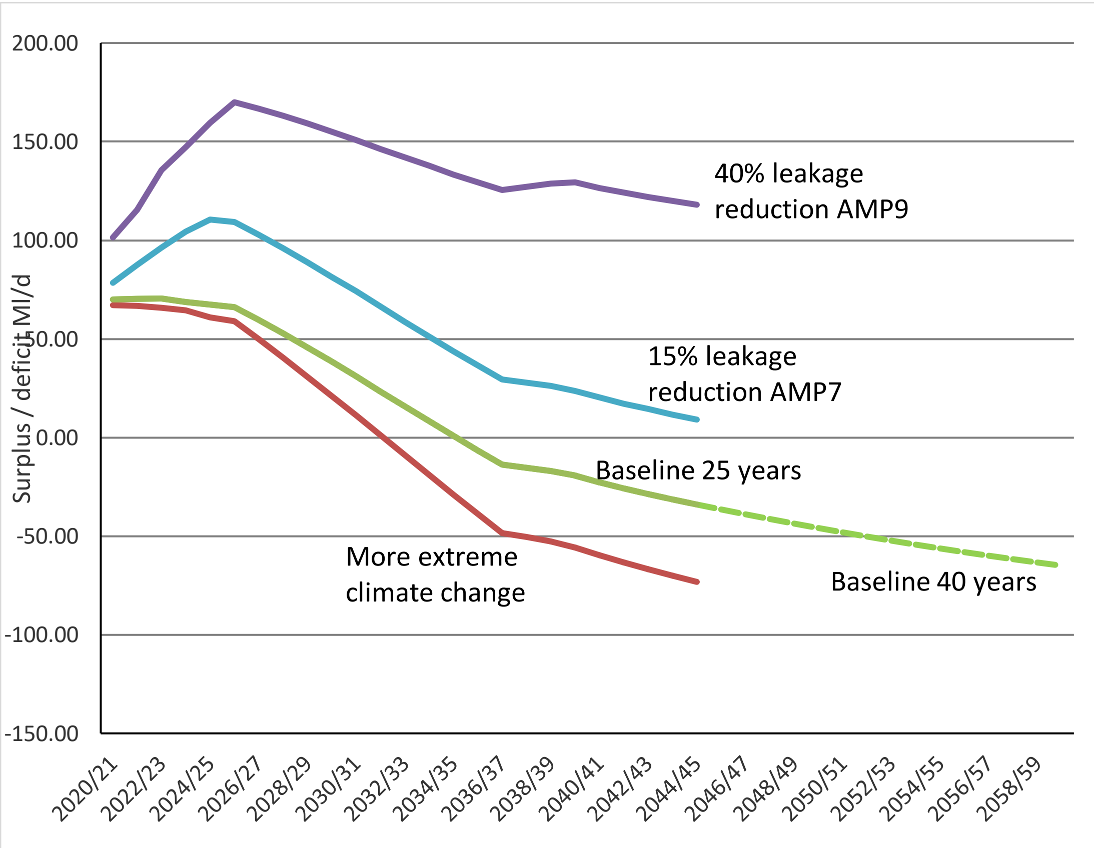


Figure 9.8 shows the surplus / deficit of each scenario. The WRIO optimisation model has been run for the scenarios resulting in a supply demand deficit. The least cost WRIO output for Scenario 1 is shown in Section 9.5, and the least cost solutions to scenarios 2 and 3 are discussed in Sections 9.7.1 and 9.7.2. Scenarios

4 and 5 result in a surplus and Sections 9.7.3 and 9.7.4 show the solutions required to achieve these scenarios.

Scenarios 2 and 3 provide a supply demand balance worse than the baseline (Scenario 1) driven by climate change. Risks to the supply forecast in addition to climate change are considered in Section 3.14, and no further future supply scenarios have been identified for WRMP19.

Demand is not driving a deficit in the supply demand balance and we have not identified any alternative demand forecasts to the baseline driven by regional demand or cross sector demand. We do however recognise that the solution to our forecast deficit could have benefits outside our region or to other water abstractors if we create a surplus in the future.

9.7.1 Scenario 2: More extreme climate change solution

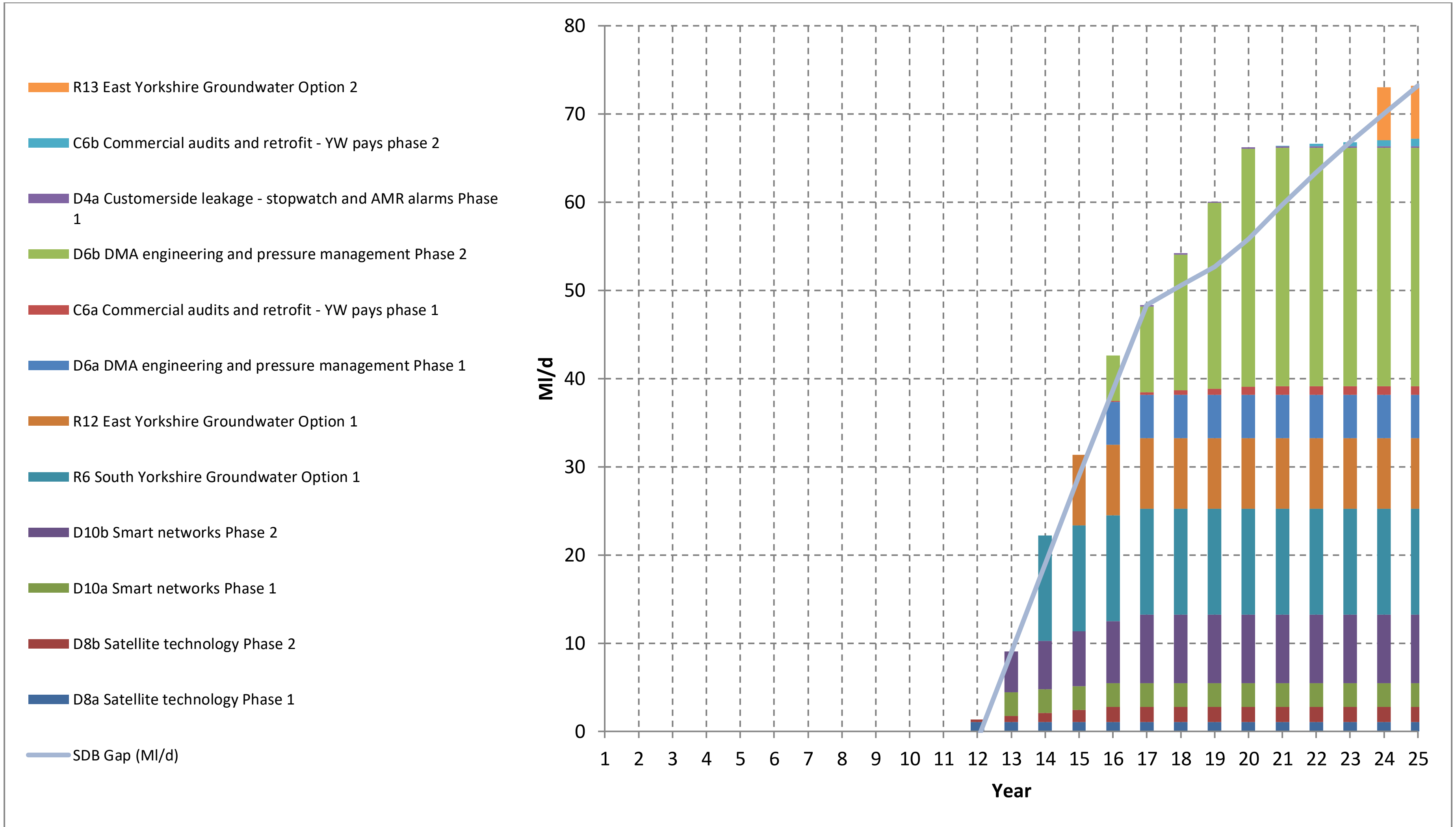
Scenario 2, a more extreme climate change scenario has forecast supply based on the median climate change scenario excluding outliers. The supply demand balance for Scenario 2 results in a deficit of 9.01Ml/d starting in 2032/33 (year 13) and increasing to 73.20Ml/d by 2044/45 (year 25).

We have produced a solution to this scenario based on the EBSD least cost approach. The solution, shown in Figure 9.9, is to implement twelve of the feasible options, nine of which are distribution management options and three resource options. It includes all the options selected to meet the least cost solution for the 25-year planning scenario, three additional phases of leakage reduction activity, one addition water efficiency option and one additional resource option.

Distribution management accounts for 64% of the total solution benefit. Two of the demand reduction options are to deliver water efficiency to non-household water users and the remaining seven would reduce leakage.

The two non-household water audit and retrofit options (C6a and C6b) would each be delivered over a five-year period to reduce demand by 1Ml/d. The seven leakage reduction options would reduce leakage by a total of 45.32Ml/d or 16% of the 2019/20 target of 287Ml/d.

Figure 9.9 Secnario 2: Least cost solution to more extreme climate change



The three supply side options included in the solution make up 36% of the benefit and are options R6 South Yorkshire Groundwater Option 1, R12 East Yorkshire Groundwater Option 1 and R13 East Yorkshire Groundwater Option 2. The three options provide an additional 26Ml/d of supply by making use of currently under-utilised Yorkshire Water licenced abstractions (R6 and R12) and by relocating an existing licence that is currently unusable due to water quality issues (R13).

All three of the resource options involve existing borehole licence capacities that are being investigated as part of the WINEP program and the future yield benefit is uncertain. R6 South Yorkshire Groundwater Option 1 and R12 East Yorkshire Groundwater Option 1 were also part of the least cost solution.

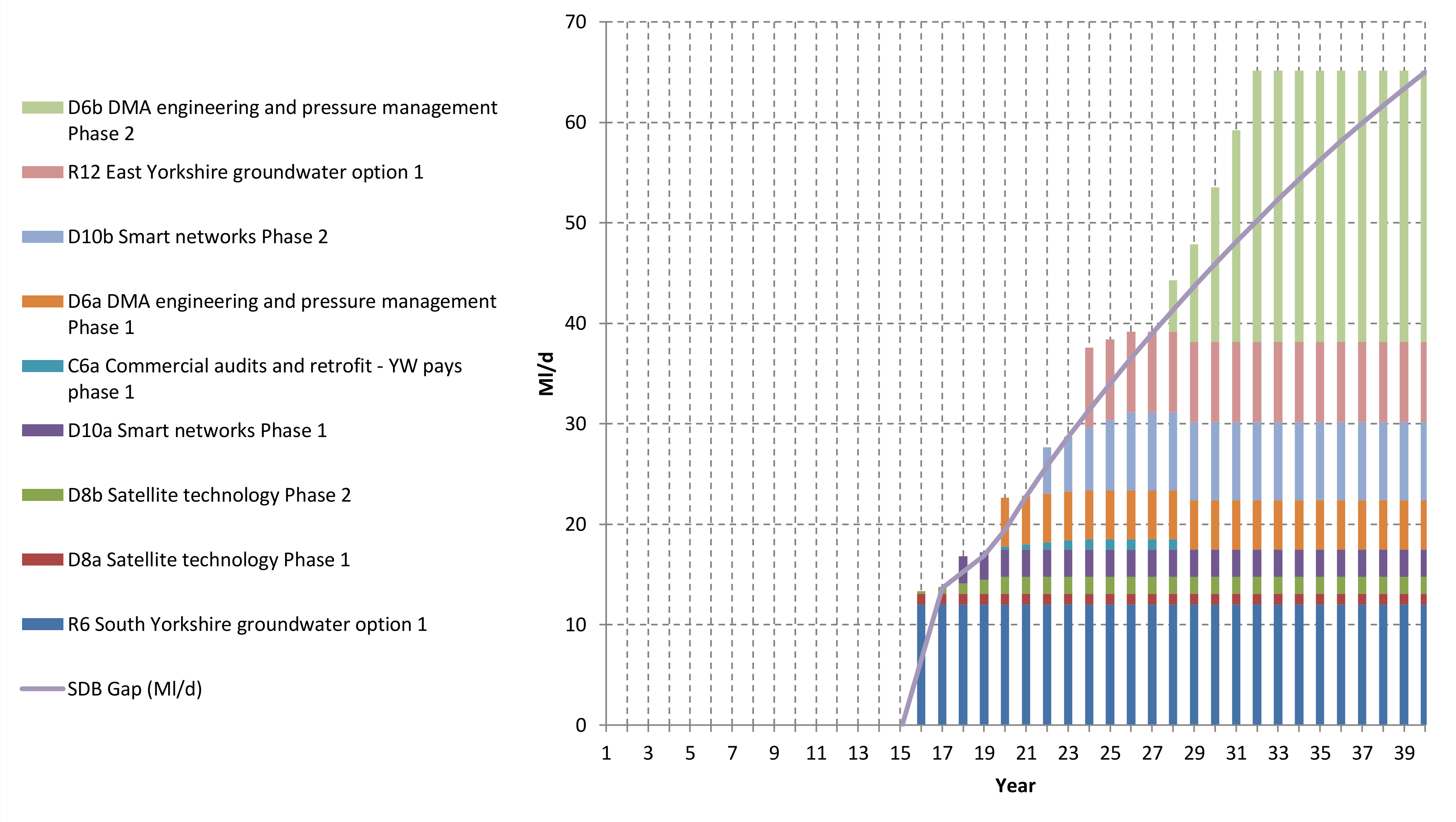
9.7.2 Scenario 3: Baseline extended to a 40-year period solution

The third Grid SWZ scenario extends the baseline scenario (Scenario 1) by 15 years to determine the solution to a 40-year supply demand forecast. The deployable output forecast for Scenario 3 extends the baseline climate change impact and supply continues to reduce throughout the planning period. The demand forecast is calculated by continuing the consumption trend of the 25-year forecast to year 40 of the extended planning period, as described in Section 4.6.

The deficit of 33.97Ml/d in year 25 (2044/45) of the baseline scenario increases to 64.99Ml/d by the end of the extended planning period (2059/60). The solution to Scenario 3 is shown in Figure 9.10 By 2059/60 this solution would implement nine options, made up of seven distribution management options and two resource options. It includes all the options selected to meet the least cost solution for the 25-year planning scenario and two additional phases of leakage reduction activity.

Distribution management options make up 69% of the solution and consist of six leakage reduction options and one water efficiency option. This scenario would reduce leakage by a total of 45.16Ml/d or 16% of the 2019/20 target of 287Ml/d. The remaining 31% of the deficit is met by two resource options, which are the same resource options (R6 and R12) contributing to the least cost 25-year baseline solution (Scenario 1) and included in extreme climate change scenario (Scenario 2). Both of these solutions carry some uncertainty related to WINEP investigations.

Figure 9.10 Scenario 3: Baseline scenario extended to a 40 year period



9.7.3 Scenario 4: 15% leakage reduction

Our fourth scenario implements a 15% reduction in leakage by 2025. We have included this scenario in response to regulatory preferences.

Ofwat proposed in its draft PR19 methodology that water companies deliver ambitious leakage reductions. This outlines that companies will need to achieve the following minimum reductions during AMP7 (2020 to 2025) or justify why not:

- at least a 15% reduction (one percentage point more than largest reduction commitment at PR14); and
- largest actual percentage reduction achieved by a company since PR14.

The *Guiding principles for water resource planning* (Defra, 2016) include a requirement for water companies to continue a downward trend in leakage reduction and set challenging leakage targets, informed by customers' views on leakage and potential for innovation in the future.

The *Water Resources Planning Guideline* (Environment Agency and Natural Resources Wales, 2017) advises water companies to include a scenario for reducing leakage by 15% in 2020-25, as indicated in Ofwat's draft methodology for PR19, and show the effects of this on supply and demand options.

Our leakage target at the end of AMP6 (2019/20) is 287Ml/d and a 15% reduction over AMP7 reduces it to 244Ml/d by 2025. To achieve the 15% reduction, we have investigated new leakage techniques and the costs for delivery. We have identified the leakage reduction options that we could feasibly implement, and these are described in Appendix A.2. These options are included in our WRIO optimisation model and were available for selection in all five of our scenarios.

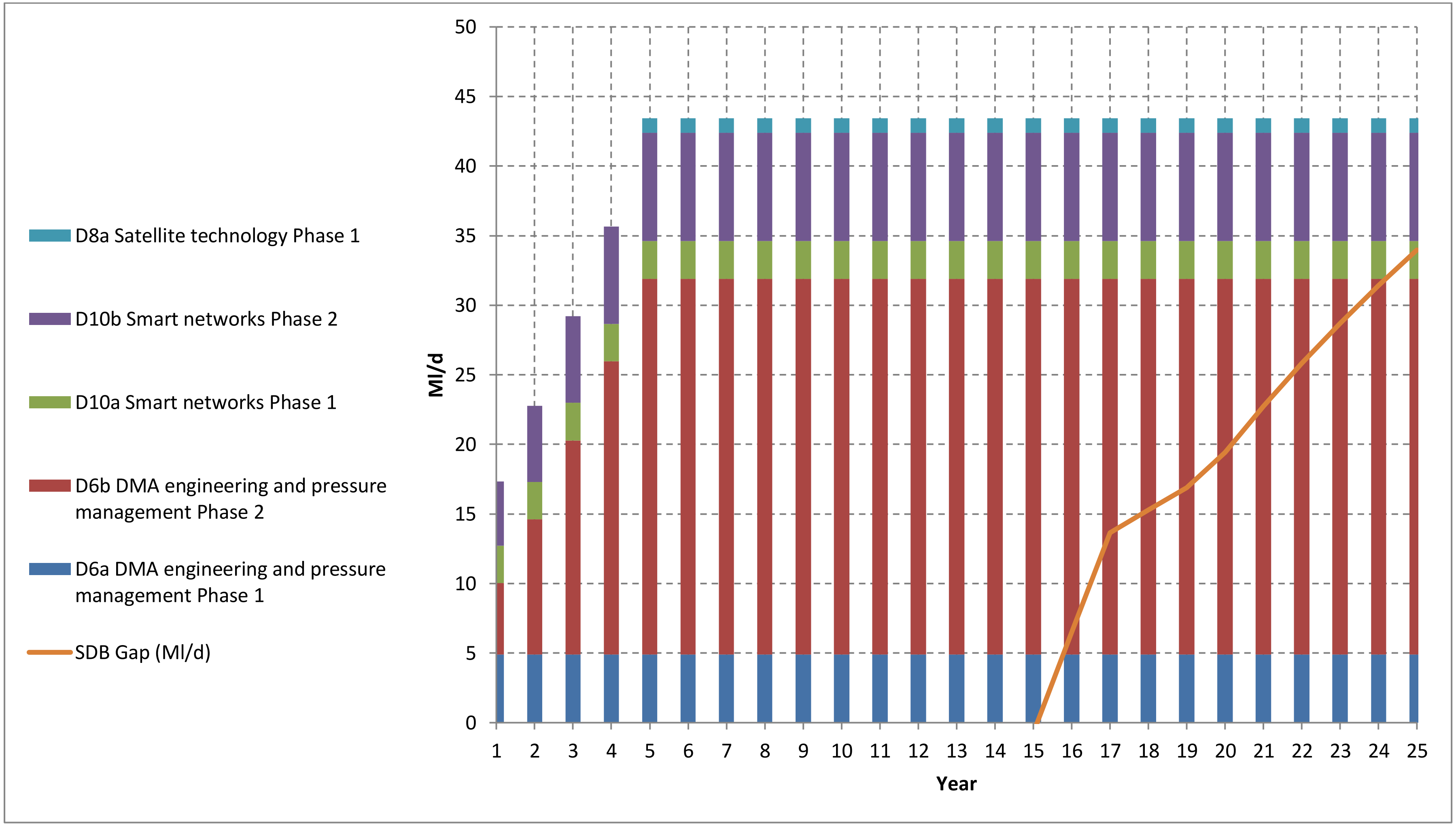
We have used our WRIO optimisation model to select the least cost solution from all the available leakage options to achieve a 15% (43.1Ml/d) reduction against our current leakage target of 287.1Ml/d between 2020 and 2025.

In total, we have eight feasible leakage options available to us, each divided into phases in WRIO to allow flexibility in the timing of implementation. This results in a total of 52 phases of leakage reduction available for selection.

Five of the feasible leakage option phases have been selected to provide the solution to Scenario 4, baseline scenario plus a 15% leakage reduction. The programme to deliver the least cost leakage options to achieve the 15% reduction in leakage by 2025 is shown in Figure 9.11

The additional demand reduction measures in the Scenario 4 solution equate to 43.45Ml/d leakage reduction. As the 15% leakage reduction strategy implements this demand reduction by 2025, the baseline Grid SWZ deficit of 33.97Ml/d in 2044/45 is met without the need for any further measures over the 25-year baseline scenario.

Figure 9.11 Scenario 4: Solution to achieve a 15% reduction in annual leakage by 2024/25



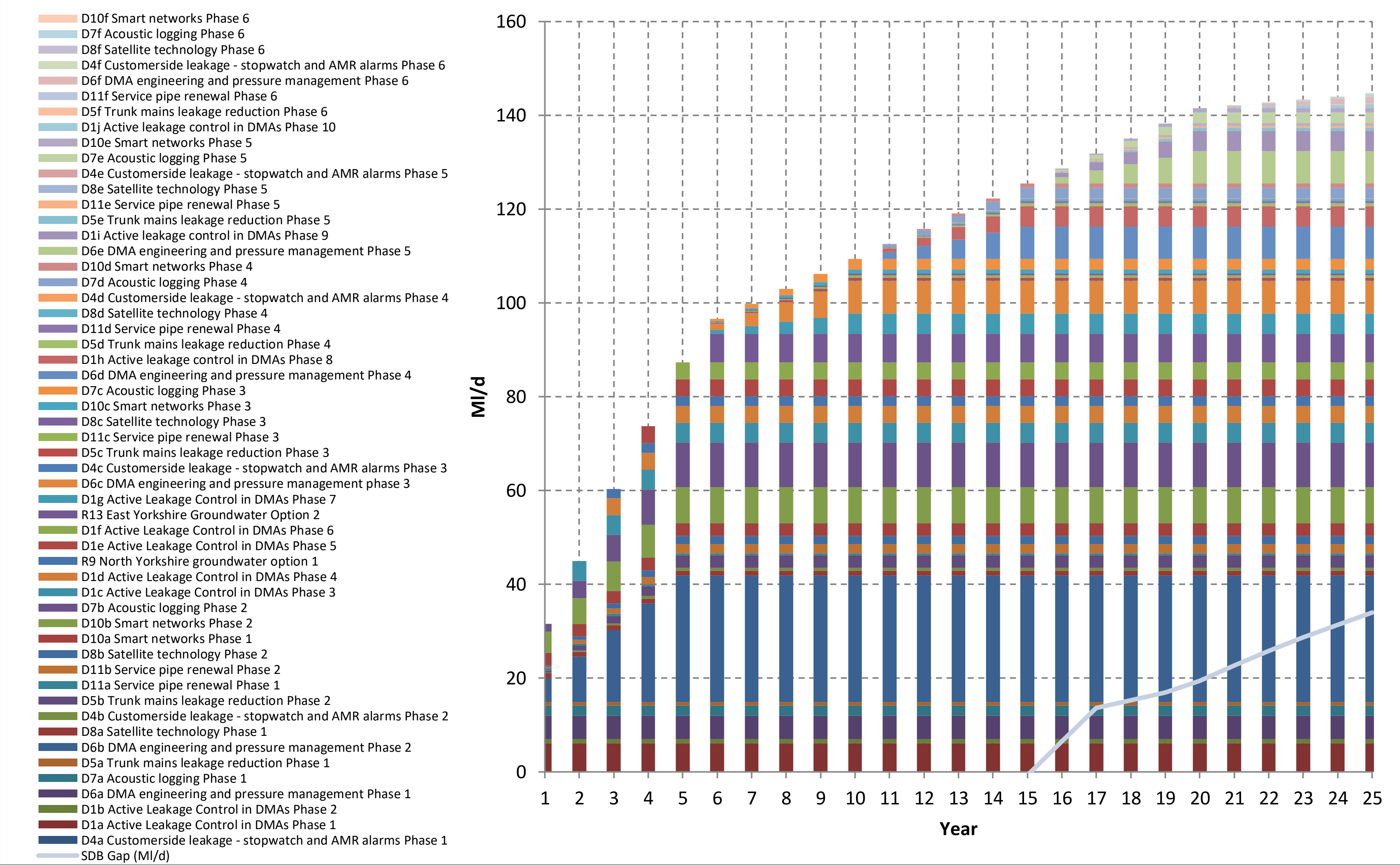
9.7.4 Scenario 5: 40% leakage reduction by AMP9

The Yorkshire Water regional leakage target in the base year of WRMP19 is 297Ml/d. Our fifth scenario implements a 40% reduction in the base year leakage target by AMP9 and continues to reduce leakage until the end of the 25 year planning period. This is in line with the Environment Agency Water resource planning guidelines stating an expectation for water companies to continue to reduce leakage beyond 2025, following the National Infrastructure Commission (NIC) report on England's Water Infrastructure.

This scenario requires implementation of all eight of the feasible leakage reduction options by 2044/45. The leakage reduction options to achieve this target will be made in the Grid SWZ. In our draft WRMP19 the 40% leakage reduction scenario aimed to meet this target by 2024/25, the last year of AMP7. This scenario has been revised for this final WRMP to achieve the 40% leakage reduction by AMP9.

Figure 9.12 shows the programme of implementation of the eight leakage options required to reduce leakage by 40% by AMP9 and to continue to reduce leakage until the end of the planning period. Each option is delivered in phases over 25 years from 2020/21 to 2044/45. We have included further leakage reduction from AMP9 onwards to demonstrate our ambition to continue to reduce leakage over the long term. In the last five years of the planning period we forecast leakage reduction will be at a much lower rate as it becomes more difficult to identify and fix leaks as leakage approaches background leakage levels. In future WRMPs we will consider any new techniques that become available and review our leakage target with each iteration.

Figure 9.12 Scenario 5: Grid SWZ baseline scenario with 40% leakage reduction by AMP9



10 Grid Surface Water Zone preferred solution

This section of our WRMP describes how we have used all the information presented within this plan to identify our final planning scenario – our preferred solution.

We have chosen to implement a significant leakage reduction programme as our preferred solution for meeting the forecast deficit identified in the Grid SWZ 25-year baseline scenario. In addition to this we will investigate a number of supply side options that, if implemented, will provide additional resilience in the Grid SWZ. The total benefit to the Grid SWZ will be 145Ml/d against a baseline deficit of 34Ml/d by 2045. This will produce a surplus in our supply demand balance which will meet our ambition to deliver an ambitious leakage reduction and provide additional resilience to a future deficit worse than our baseline scenario, as presented in our Scenario 2 more extreme climate change solution and Scenario 3 baseline extended to a 40-year period.

The leakage activity we will carry out will deliver the leakage options presented in Scenario 5 above, but we will start the leakage reduction programme a year earlier. An initial reduction is made in 2019/20 to reduce regional leakage to 269Ml/d, which is a 9% decrease from the base year leakage target of 297Ml/d. In AMP7 the regional leakage target will be reduced by 25% from 269Ml/d to 202Ml/d. From 2025 onwards, we will reduce leakage to meet a regional target of 176Ml/d by 2032/33, which is more than 40% of the base year target of 297Ml/d. We will continue to reduce leakage to the end of the 25 year planning period to reach a target of 150Ml/d by 2044/45.

In our draft WRMP19, to put us in a position whereby we could achieve a 40% reduction by 2024/25 we started an enhanced leakage reduction programme in 2018/19. The baseline leakage target for 2018/19 was 292Ml/d and for 2019/20

287Ml/d, as determined in the WRMP14 and referred to as our regulatory leakage target. Our draft WRMP19 40% leakage reduction scenario was based on revised leakage targets for the last two years of AMP6, 276Ml/d in 2018/19 and 236Ml/d in 2019/20.

In 2018/19 we achieved a regional leakage value of 290Ml/d. We therefore achieved out regulatory target of 292Ml/d but not the target proposed in our draft WRMP19. In 2018/2019 our region experienced drought conditions. During hot, dry weather the soil becomes very dry which leads to increased ground movement. This ground movement causes an increase in the number of leaks on our network and makes it much more difficult to achieve leakage targets. We have revised our 40% leakage reduction scenario to take into account the leakage of 2018/19 and the target for 2019/20 in the 40% leakage reduction scenario is 269Ml/d. However, the regulatory target will remain at 287Ml/d as determined in WRMP14.

In addition to the leakage reduction described above, we will investigate three supply options to provide additional resilience, R9 North Yorkshire Groundwater option 1, R13 East Yorkshire Groundwater option 2 and R72 River Wharfe licence increase and one supply side option (R63 North Yorkshire Groundwater 2) as an alternative to a clean water distribution solution in our PR19 Business Plan.

Options R9 North Yorkshire Groundwater option 1 and R13 East Yorkshire Groundwater option 2 are scheduled for implementation in 2022/23 and 2025/26 respectively, provided the results of the investigations determine that the licences are sustainable, and the Environment Agency grants licence variations to the existing licences. These two options will provide additional resilience to outages in the Grid SWZ. Although not essential to meeting the deficit in the Grid SWZ, they do provide deployable output benefit to the zone's dry year annual average scenario and are included in the solution presented in the final planning tables.

The River Wharfe licence increase (R72) will provide additional winter resilience if we experience high summer demands followed by high winter demands. However, it will not provide a benefit to our dry year annual average Grid SWZ scenario and is therefore, not include in the final planning tables.

We have identified a risk of increased population growth in a rural area of our Grid SWZ. Recent development is putting pressure on a local borehole that predominantly supplies the area and we are transferring additional supply via existing grid connections. To reduce pressure in this area in the short term we have applied to the Environment Agency for a licence increase on the existing boreholes. However, there is a risk of further housing development in the area and our PR19 Business Plan has identified a long-term solution to install an additional pipeline to link the area to a large water treatment works in the Grid SWZ.

As an alternative to the pipeline we could invest in additional infrastructure to increase abstraction from the existing borehole. This alternative solution is dependent on the Environment Agency granting the variation on the borehole abstraction licence. The two options have been considered in this WRMP as R62 North Yorkshire rural distribution enhancement and R63 North Yorkshire Groundwater 2.

The solution will need to be selected and implemented in AMP7. Neither solution will result in an increase to the Grid SWZ deployable output as the clean water distribution option (R62) will utilise an existing resource and the borehole licence variation (R63) will slightly increase a local source, making a small quantity of water available in the grid, but will not increase the deployable output of the Grid SWZ.

10.1.1 Our decision-making process

In selecting our preferred plan, we have chosen a solution that minimises environmental risks, meets customer and regulatory preferences and is flexible and sustainable in an uncertain future. This is in line with the needs we, our customers and our stakeholders identify as priorities in our new long-term strategy for Yorkshire Water, and with the six capitals approach that we are embedding into our business plan and day to day approaches.

Through a broad consideration of risks and impacts across the six capitals (financial, manufactured, natural, social, human and intellectual) we can make more informed long-term decisions that recognise the inherent trade-offs between environmental, financial and societal costs and benefits.

During the development of the draft WRMP19, we were very conscious of the challenge set by Ofwat in the draft PR19 methodology regarding reductions in leakage and the link between this and the strategy guidance from the UK government. The UK Infrastructure Commission has also recommended that reductions in leakage should be a priority. These challenges resonated strongly with messages we received from our customer engagement, and also the work on the foundations for our new long-term strategy. Our focus on the Total Impact Value Assessment and Six Capitals model emphasises the importance of demand-side rather that supply-side solutions, and so in identifying solutions for the emerging deficit in the mid-2030s, our immediate focus was on leakage reduction.

Our analysis showed that a leakage reduction of 15% would be sufficient to close the emerging deficit, and this would also satisfy one element of Ofwat's leakage challenge. However, the leakage challenge in the draft methodology had several component parts: the requirement for all companies to achieve upper quartile performance, and then to improve by a further 15%. It was this dual challenge that led to the 40% leakage target we proposed in our draft WRMP19.

Historically, we have set and met targets for leakage at the level indicated by SELL. Our relative abundance of water resources and our ability to move water around our region using our water grid has resulted in our on-target leakage performance being at a higher relative level than companies in more water stressed areas. To close the gap to upper-quartile performance requires a 25% improvement, therefore the 40% target represented a combination of this catch-up and the additional 15% stretch.

The decisions to include a 40% leakage reduction were taken by our Board immediately after publication of the final methodology, and the Yorkshire Forum for Water Customers were consulted throughout. A key feature of our approach was to start our PR19 plan early by re-investing totex outperformance savings to improve performance across the four common upper-quartile performance commitments, with our Shareholders forgoing incentive payments (or a possible reduction in gearing) to do this. The Customer Forum were consulted both on the nature of the revised targets and in the use of the totex incentive to fund these.

Since publishing our draft WRMP in 2018 we have extended the time to achieve the 40% reduction. Our WRMP now forecasts we will reduce leakage levels to 40% of the base year level by 2033 rather than 2025 as proposed in the draft WRMP19. We are still focused on achieving additional leakage but decided to rebase the timeframe for achieving the 40% reduction following high leakage levels in 2018/19. We did not meet the draft WRMP19 target for 2018/19 as leakage levels in this year were high as a result of ground movement during the dry summer of 2018.

Our focus on leakage was supported by a number of considerations, two concerning other demand side solutions and two supply side alternatives:

The estimated per capita consumption of Yorkshire customers is already low, indicating that further progress may be challenging. We also believe that reducing leakage is an essential precursor to customers' demand management. Without significantly reducing leakage, it is likely to be more difficult to persuade customers to reduce their own consumption. As part of our overall PR19 plan, we also have a stretching target to reduce per capita consumption further.

As our supply area does not meet the definition of being water stressed, we do not have any basis (under current arrangements) to adopt universal metering. Our focus remains on an optant-led policy. As described previously, we are also introducing a new commitment to identify customers who might benefit from a metered supply, and pro-actively contact such customers to encourage them to consider opting for a meter.

For supply side options our first consideration was around the long-term sustainability of such approaches given the impact on our consumption of natural capital. Our customers have emphasised the importance of environmental improvements and given the long-term population growth and climate change projections, we consider it is important to adopt good practice as soon as possible. So even if expansion of supply side options produced a lower near-term incremental cost than some aspects of leakage reduction, the long-term costs (particularly when considering a six-capital approach) point to demand side rather than supply side options.

The second supply side option consideration was the potential future development of water trading. We believe that the environment for trading will be substantially improved if a company has already driven forward on leakage reduction. If a company has not improved its leakage performance, this will tend to act as a barrier to trading. Third parties may be less interested in developing possible traded options if they are effectively competing against improved leakage performance. Reducing leakage may also open up opportunities for trading the water resources that are saved.

The two borehole solutions included in our preferred solution for meeting the Grid SWZ deficit were identified outside of the supply-demand balance calculation and not selected to meet the deficit. The R13 East Yorkshire Borehole option is being implemented to replace the current licence in this area, where the borehole has not been used in recent years due to bacteria contamination. Alternative sources in the grid system have meant we could meet demand without this licensed resource. However, our PR19 maintenance programme has identified we should bring the borehole back into supply to ensure we are resilient to future risks of increasing nitrates at nearby boreholes and uncertainty over licence reductions in this area due to WINEP. We could therefore invest in the current site to bring it back into supply. However, it was identified that a relocation of the borehole would reduce the risk of the maintenance scheme failing due to the bacteria at the original site.

The R9 North Yorkshire groundwater option 1 was selected to provide security to a local area where we can meet current and future demand with current sources as it can be supported from a nearby, larger treatment works. However, there is much uncertainty over potential housing development in the area and the source was identified as a low cost solution (£10,000 capital cost)) to increase resilience when outages occur in the future. The alternatives to the borehole licence variation would be one of the options to transfer water from the Tees to the Dales (R49, R50 or R51). These options would incur capital costs of between £13 million to £50 million, provide resource in excess of what was required (15Ml/d) and have a greater environmental impact due to the infrastructure required to transfer the water.

In 2019 we submitted an application for a licence variation to increase permitted abstraction from a second borehole in the North Yorkshire area. The licence increase would provide support to the local area and with investment in additional treatment facilities could be used as an alternative to a PR19 Business Plan scheme. The PR19 scheme is to link a village in North Yorkshire to a large water treatment works in the Grid SWZ. This is discussed in Section 12.1.

We also plan to apply for a variation on an existing abstraction licence on the River Wharfe in AMP7. An increase in the annual permitted abstraction volume will provide additional resilience against winter freeze-thaw events. Utilisation of the additional volume is dependent on the Grid SWZ experiencing high winter demands and the resources being available (high river flows and / or support from an upstream reservoir). This additional abstraction permission would provide resilience in extreme years where demand has been high during the summer months and we have had to draw on both river and reservoir resources more than we would in a normal year. We benefit from this additional resource in a cold year but not in a dry year, although a dry year could be a contributing factor to the need for the increased volume.

The River Wharfe licence increase option requires a licence variation to be granted by the Environment Agency to allow an increase in the current annual abstraction limit by 10Ml/d, from 65.05Ml/d to 75.05Ml/d. The daily and instantaneous limits on the licence conditions would not be changed. No additional infrastructure is required to implement this option. The costs incurred are for the licence application (less than £500) and operating the scheme. Operational costs will be minimal over the 25-year planning period as the additional volume would not be required in an average year.

The River Wharfe option is a drought permit option in our Drought Plan 2019. A permanent licence increase would provide our region with greater resilience if we experience extreme cold weather such as the Beast from the East in 2017.

The hydrological impacts of this option have been assessed in detail in support of our Drought Plan 2019; the assessment concluded a potential minor reduction at moderate and high river flows in the River Wharfe (downstream of the river intake and the tidal limit) within the flow envelope associated with normal river flows. At

low river flows abstraction is a portion of the water released from an upstream reservoir as regulation release. Overall this is considered a negligible hydrological effect given that it would not be discernible when compared with the range of winter flows in the river, and freshwater flows into the estuary will not be affected.

Alternatives to R72 River Wharfe licence increase, that would provide a similar level of winter resilience certainty, include our other supply side WRMP options. However, this is our preferred option as the financial costs and environmental impacts are minimal and avoid the need for new infrastructure.

10.2 Summary of risks to the Grid SWZ supply demand balance

The Grid SWZ baseline 25-year scenario and the sensitivity testing we have carried out using a more extreme climate change scenario and extended planning period has identified risks to the supply demand balance of this zone. In addition to this, our investigations into headroom and potential outages that we could experience in the future and our review of the 2018 drought has highlighted a need to enhance resilience in the zone. In summary, the following risks have been identified:

- Climate change is likely to significantly impact on future supply, but the scale and timing of the deficit is uncertain.
- Headroom and outage risks due to pollution are currently mitigated through our conjunctive use system within the Grid SWZ. However, where water quality is deteriorating there is a risk of more severe outages in the future.
- WINEP investigations could lead to sustainability reductions on some of our groundwater sources. This will not impact on deployable output but could reduce the availability of blending sources that allow us to avoid outages due to nitrate/turbidity pollution, particularly in the East Yorkshire area of the Grid SWZ.
- WINEP has also identified a risk of a future sustainability reduction on a key river abstraction on the River Derwent. The risk is due to a potential change to the revised Common Standards Monitoring

Guidance. There is insufficient evidence to create a scenario for this potential risk for WRMP19.

- In AMP7 we will investigate the resilience of key water treatment works in our region in the event of outages not previously experienced. Under current demand our integrated system has managed previous outage events without interruption to supply. However, it is recognised that in areas where new housing developments are planned there will be greater pressure on key water treatment works during outage events and future investment to enhance resilience in our grid system could be needed.
- In 2018 we experienced a prolonged period of dry weather and high demands which triggered drought actions. This instigated some revisions to the Drought Plan and identified a need for increased resilience against the risk of experiencing a dry summer combined with high summer demand followed by high winter demand (freeze-thaw).

The least cost solution to the baseline scenario (Scenario 1) is met by five distribution management (41%) and two resource schemes (59%). Our scenario testing on a more extreme climate change scenario (Scenario 2) and an extended planning period (Scenario 3) showed further interventions could be required in the future.

The supply side schemes selected in the least cost solutions to Scenario 1 are R6 South Yorkshire Groundwater option 1 and R12 East Yorkshire Groundwater option 1. The solution to Scenario 2 includes both R6 and R12 and one additional resource option, R13 East Yorkshire Groundwater Option 2. Scenario 3 also includes R6 and R12. As well as increasing available resources in the Grid SWZ to help meet the deficit, schemes R6, R12 and R13 would enhance the resilience of the zone by increasing the potential to move water around the region when outages or peak demands occur.

Two of the resource schemes, R6 and R12 would make use of existing licenced resources that are currently underutilised. However, the two schemes are included

in WINEP and investigations will be carried out in early AMP7. This creates some uncertainty over the sustainability of the options and may result in a reduced yield benefit.

Although we are not forecasting a deficit in our baseline supply demand balance until 2035/36, we need to implement a solution that will be sustainable to future risks, and for this WRMP the uncertainty over the two supply side schemes means we must consider alternative solutions. However, AMP7 investigations will help confirm the feasibility of the options for WRMP24.

Option R13 East Yorkshire Groundwater option 2, which is included in Scenario 2 and the preferred solution, will relocate an existing licence provided the Environment Agency approve our licence application. The current licence is not used but is included in WINEP. We have selected this option to provide resilience and the demand reduction from the leakage options will close the future supply demand deficit. We are not relying on the R13 resource to meet the supply demand balance. Investigations will be carried out to understand the environmental impacts of the potential abstraction. If the investigation results in a reduced benefit the source would still provide resilience as it will be used in conjunction (under current infrastructure) with the East Yorkshire boreholes, which may also be reduced as a result of WINEP investigations.

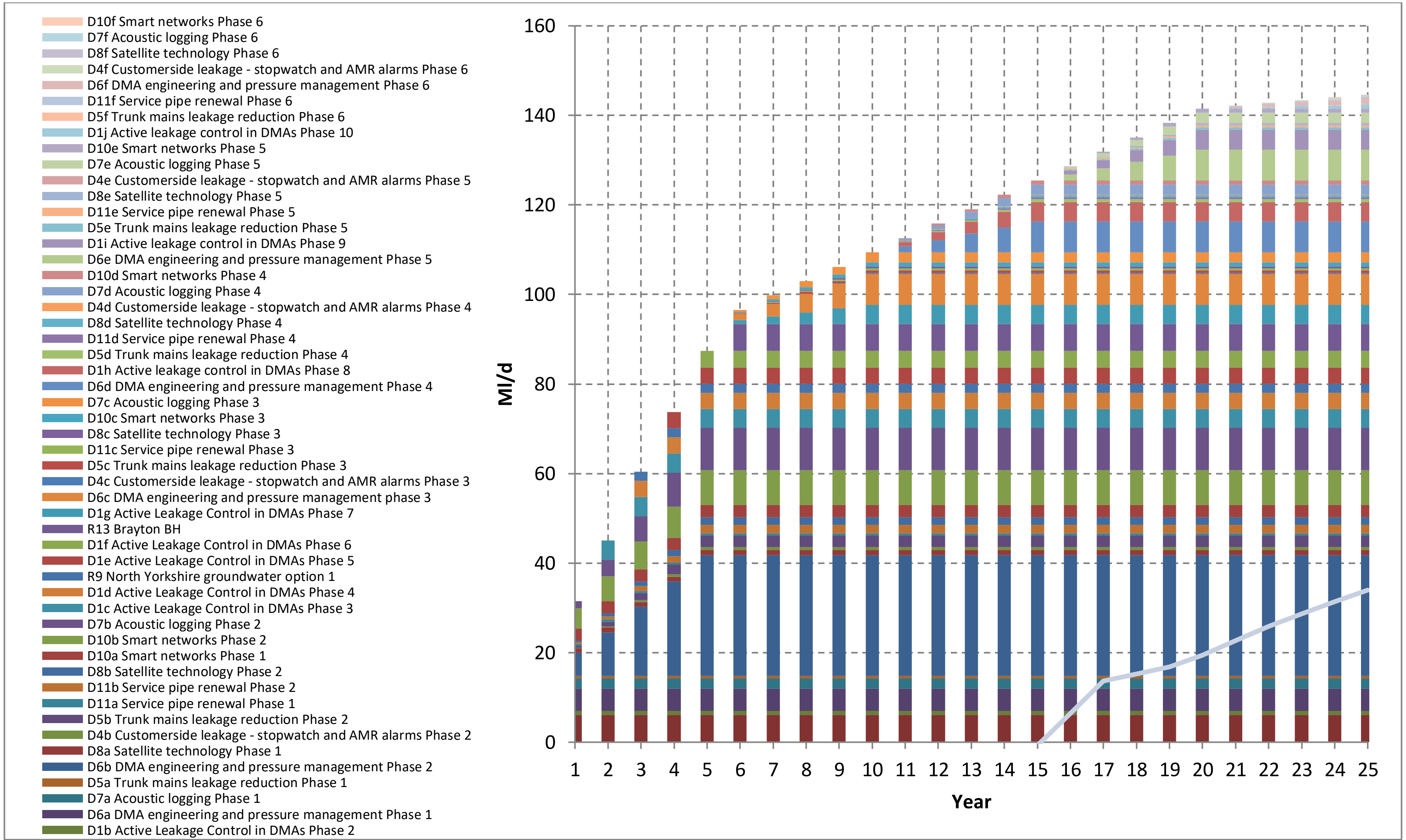
10.3 Benefits of the Grid SWZ preferred solution

Our preferred solution to reduce leakage by 40% by AMP9, with further reductions up to 2045, and to invest in two new supply schemes will address the forecast deficit, help maintain resilience to future outage risks and provide a surplus if climate change is more severe than the baseline forecast. The forecast supply/demand balance with our preferred solution implemented is shown in Figure 10.1 The full benefits of the preferred plan are outlined below:

- Meet the baseline scenario supply demand deficit, securing our levels of service over the 25-year planning period.
- Meet Defra’s expectation for a downward leakage trend.

- Achieve Ofwat's requirements for at least 15% leakage reduction target by 2025, whilst also improving our own leakage performance significantly when compared to the rest of the UK water industry.
- Meets our own and customer preferences to reduce leakage and to take less water from the environment.
- Deliver a social and wellbeing benefit to customers by reducing the volume we abstract from rivers and reservoirs that they use for recreation.
- Provide resilience to outages by developing two new resources and reducing the average daily demand required from our key water treatment works. Overall water into supply will reduce, therefore the two new supply schemes are required for resilience only and will be used in conjunction with other sources to alleviate outage risks.
- Relies on demand reduction, providing a more sustainable solution than new supplies if water becomes scarcer in the future through further sustainability reductions or Abstraction Reform.
- Reduces our daily energy and chemical consumption, and the resultant carbon footprint, by reducing the volume of water we are required to treat and deliver through our supply network.
- Increases flexibility of choice over where we source and treat water to put into supply so that we can avoid more polluted water sources that require advanced treatment.
- An early start on implementation will ensure we can maintain demand at a lower level prior to the risks of climate change reducing supply to a critical point. It will also mitigate any reduction to our River Derwent licenced abstraction.
- In the event of droughts, we will be more resilient and not require as much reliance on drought orders and permits.

Figure 10.1 Grid SWZ preferred solution for the 25 year baseline dry year annual average scenario



10.3.1 Demand reduction benefits

A breakdown of the yield benefits of the preferred solution is presented in Figure 10.1 and Table 10.1. The preferred solution will deliver eight distribution management options to reduce our current leakage volume and two resource options to provide additional resilience in the Grid SWZ. Further resilience will be provided by the River Wharfe (R72) licence variation if granted by the Environment Agency and potentially the North Yorkshire Groundwater 2 option if we select this as the solution to a local supply issue instead of the current clean water distribution solution.

The leakage options will be delivered through a total of 52 phases. The first phase of each leakage option will be delivered in AMP6 to provide an early start in delivery to achieve the targeted 40% leakage reduction by AMP9. From AMP9 onwards, we aim to continue leakage reduction at a reduced rate as current leakage techniques reach their limits. However, available leakage techniques will be reviewed with each iteration of the WRMP to assess if there is greater potential to reduce leakage in the future.

The leakage reduction options will reduce water into supply by a total of 137Ml/d by 2044/45. The two resource options will provide a combined 8Ml/d additional deployable output. The demand reduction benefits of the leakage options will remove the deficit forecast to start in 2035/36 in the baseline 25-year planning period.

10.3.2 Resilience benefits of the Grid SWZ preferred solution

The resource options we have selected as part of our preferred solution are a 2Ml/d annual average and peak increase to an existing groundwater abstraction in North Yorkshire (R9) and a relocation of a 6Ml/d annual average, 9Ml/d peak groundwater licence in East Yorkshire (R13). The investment in the two borehole supplies will enhance resilience to headroom and outage risks.

The R13 East Yorkshire Groundwater Option 2 is proposed as an improved location to an existing licenced abstraction that has been closed due to bacterial contamination. The licence is no longer included in our deployable output as our conjunctive use system can meet demand and cope with outages under current conditions.

Table 10.1 Start date and yield of schemes to deliver the Grid SWZ preferred solution

Ref.	Option	First year of benefit	Year full benefit implemented	Benefit on completion (Ml/d)
D1a	Active Leakage Control in DMAs Phase 1	2019/20	2019/20	5.93
D1b	Active Leakage Control in DMAs Phase 2	2020/21	2020/21	0.95
D1c	Active Leakage Control in DMAs Phase 3	2021/22	2021/22	4.24
D1d	Active Leakage Control in DMAs Phase 4	2022/23	2022/23	3.65
D1e	Active Leakage Control in DMAs Phase 5	2023/24	2023/24	3.65
D1f	Active Leakage Control in DMAs Phase 6	2024/25	2024/25	3.65
D1g	Active Leakage Control in DMAs Phase 7	2025/26	2029/30	4.35
D1h	Active leakage control in DMAs Phase 8	2030/31	2034/35	4.35
D1i	Active leakage control in DMAs Phase 9	2035/36	2039/40	4.35
D1j	Active leakage control in DMAs Phase 10	2040/41	2044/45	0.87
D4a	Customerside leakage - stopwatch and AMR alarms Phase 1	2019/20	2019/20	0.16
D4b	Customerside leakage - stopwatch and AMR alarms Phase 2	2020/21	2024/25	0.68
D4c	Customerside leakage - stopwatch and AMR alarms Phase 3	2025/26	2029/30	0.16
D4d	Customerside leakage - stopwatch and AMR alarms Phase 4	2030/31	2034/35	0.16
D4e	Customerside leakage - stopwatch and AMR alarms Phase 5	2035/36	2039/40	0.16
D4f	Customerside leakage - stopwatch and AMR alarms Phase 6	2040/41	2044/45	0.03
D5a	Trunk mains leakage reduction Phase 1	2018/19	2018/19	0.63

Ref.	Option	First year of benefit	Year full benefit implemented	Benefit on completion (Ml/d)
D5b	Trunk mains leakage reduction Phase 2	2020/21	2024/25	2.62
D5c	Trunk mains leakage reduction Phase 3	2025/26	2029/30	0.62
D5d	Trunk mains leakage reduction Phase 4	2030/31	2034/35	0.62
D5e	Trunk mains leakage reduction Phase 5	2035/36	2039/40	0.62
D5f	Trunk mains leakage reduction Phase 6	2040/41	2044/45	0.12
D6a	DMA engineering and pressure management Phase 1	2018/19	2018/19	4.89
D6b	DMA engineering and pressure management Phase 2	2020/21	2024/25	27.01
D6c	DMA engineering and pressure management phase 3	2025/26	2029/30	6.90
D6d	DMA engineering and pressure management Phase 4	2030/31	2034/35	6.90
D6e	DMA engineering and pressure management Phase 5	2035/36	2039/40	6.90
D6f	DMA engineering and pressure management Phase 6	2040/41	2044/45	1.38
D7a	Acoustic logging Phase 1	2018/19	2018/19	2.26
D7b	Acoustic logging Phase 2	2020/21	2024/25	9.42
D7c	Acoustic logging Phase 3	2025/26	2029/30	2.24
D7d	Acoustic logging Phase 4	2030/31	2034/35	2.24
D7e	Acoustic logging Phase 5	2035/36	2039/40	2.24
D7f	Acoustic logging Phase 6	2040/41	2044/45	0.45
D8a	Satellite technology Phase 1	2018/19	2018/19	1.06

Ref.	Option	First year of benefit	Year full benefit implemented	Benefit on completion (Ml/d)
D8b	Satellite technology Phase 2	2020/21	2024/25	1.71
D8c	Satellite technology Phase 3	2025/26	2029/30	0.41
D8d	Satellite technology Phase 4	2030/31	2034/35	0.41
D8e	Satellite technology Phase 5	2035/36	2039/40	0.41
D8f	Satellite technology Phase 6	2040/41	2044/45	0.08
D10a	Smart networks Phase 1	2018/19	2018/19	2.70
D10b	Smart networks Phase 2	2020/21	2024/25	7.79
D10c	Smart networks Phase 3	2025/26	2029/30	0.91
D10d	Smart networks Phase 4	2030/31	2034/35	0.91
D10e	Smart networks Phase 5	2035/36	2039/40	0.91
D10f	Smart networks Phase 6	2040/41	2044/45	0.18
D11a	Service pipe renewal Phase 1	2018/19	2018/19	0.46
D11b	Service pipe renewal Phase 2	2020/21	2024/25	1.93
D11c	Service pipe renewal Phase 3	2025/26	2029/30	0.46
D11d	Service pipe renewal Phase 4	2030/31	2034/35	0.46
D11e	Service pipe renewal Phase 5	2035/36	2039/40	0.46
D11f	Service pipe renewal Phase 6	2040/41	2044/45	0.09
R9	Catterick Boreholes	2022/23	2022/23	6.00
R13	Brayton BH	2025/26	2025/26	2.00

Ref.	Option	First year of benefit	Year full benefit implemented	Benefit on completion (Ml/d)
			Total leakage reduction Ml/d	136.70
			Total supply increase Ml/d	8.00
			Total supply / demand benefit Ml/d	144.70

In the future, the combined risk of increasing nitrate/turbidity levels and sustainability reductions on the East Yorkshire licence group could reduce the current resilience in this area. Our long-term solution to address nitrate risks is catchment management. The R13 East Yorkshire Groundwater Option 2 would provide support to the East Yorkshire borehole group to mitigate the loss of resource due to any sustainability reduction imposed and outages due to nitrates in the short term.

Potential alternatives to R13 would be to invest in the spare licence capacity on the River Ouse and implement option R1a to increase treatment capacity or R2b Ouse raw water transfer. Both schemes would require additional infrastructure to pipe to the East Yorkshire area and incur a much greater cost than R13 East Yorkshire Groundwater Option 2. They would provide greater yield benefits, but our demand reduction schemes will help ensure these higher volumes are not required.

The 2Ml/d increase to the North Yorkshire borehole (R9) has been selected as part of our least cost solution, as with R13 it is not required to meet the baseline deficit with the leakage reduction implemented. However, we have chosen to implement the scheme to achieve the resilience benefits of the option. The additional resource will provide more flexibility in the North Yorkshire area of the Grid SWZ by reducing the need to support the area from a nearby larger water treatment works. This releases capacity at this works to provide support to other areas as required.

The alternatives to this scheme would be to implement one of the Tees to Dales options or to invest in the Ouse (R1a or R2b) schemes and additional infrastructure to transfer

to the Dales area. These schemes would be more expensive than R9 North Yorkshire groundwater option 1, but have the advantage of providing an additional 15Ml/d.

The final plan surplus will be 118.00Ml/d, which exceeds the 33.97Ml/d deficit forecast in 2044/45. The two resource options are to provide resilience against potential outages and overall our preferred solution will result in less water being taken from the environment daily.

We are not relying on the two supply side options to close the gap in the baseline scenario. The additional resource could help ensure that we are in a good position if the impact of climate change on supply is more severe than predicted in our baseline scenario. However, if the results of the investigations into the options conclude they are not sustainable, or the licences are permitted at a lower volume, then this will not create a gap in the final planning supply demand balance for this WRMP.

Since publishing our draft WRMP 19 we experienced a drought in our region. During this event we identified a licence increase on the River Wharfe (R72) would improve our resilience to high winter demands if they occurred in the same year as any future droughts. We have also identified an increase in our use of a borehole in North Yorkshire (R63 North Yorkshire Groundwater Option 2) could be an alternative to a clean water distribution solution that is included in our PR19 Business Plan. However, neither of these schemes result in an increase to the dry year annual average deployable output in the Grid SWZ.

10.4 Customer support

Appendix C details the extensive customer engagement we have carried out as a central part of PR19 and WRMP19 planning, to help us understand more about what is important to our customers now and in the future. This process has provided an appraisal of customers' views on current and potential leakage levels and the information in Appendix C has been presented with specific reference to this and other activity relevant to water resource planning.

All research undertaken was conclusive about our customers' expectations on current and future leakage performance. Customers were disappointed with our current leakage

performance and comparative industry position and expected to see significant leakage reduction prioritised over the short, medium and long term.

We also discussed our draft plan with our independent customer challenge group, the Yorkshire Forum for Water Customers. The Forum was set up in 2012 and is made up of key groups in Yorkshire who collectively represent Yorkshire Water's customers.

The Yorkshire Forum for Water Customers' Environment Sub-Group was established to support the main Forum in challenging the company's activities on issues relating to the environment. This has included consideration of Company submissions to Ofwat, the Government, the Drinking Water Inspectorate (DWI), the Environment Agency and Natural England.

The Sub Group have discussed the draft WRMP19 over many meetings and have examined the guidance, the drivers, our approach, environmental impacts, the proposed solutions, the technical papers, the assurance, the Board assurance and the public consultation. The Sub Group involvement has continued with regard to consultation representations, our statement of response and drafting WRMP19.

The Sub Group has been supportive of our process and approach to WRMP19 and reviewed and challenged a version of the draft WRMP19 documents and helped improve the clarity, coherence and readability draft WRMP19 published for consultation. The Sub Group also challenged the demand management options considering the secure supply demand balance. They requested a presentation on demand management to understand the range of activity and the reasoning for the demand management plans and the ambitious leakage target. The discussions have concluded with the group being supportive of the WRMP19.

10.5 Habitats Regulations Assessment of the preferred solution

A Habitats Regulations Assessment (HRA) has been prepared to assess the potential for likely significant effects of the WRMP options on sites designated under the Habitats Directive, Birds Directive and the international Ramsar Convention. The findings have been discussed with Natural England and the Environment Agency.

The HRA screening assessment of the preferred solution has concluded that, except for one option, and with mitigation taken into account, the preferred plan is not likely to have significant effects on the integrity of any of these designated sites based on current information and designations. There was some initial uncertainty around the R9 North Yorkshire groundwater option 1 scheme. Stage 1 HRA screening indicated that likely significant effects on the SAC could not be ruled out as a result of the implementation of the scheme. HRA Guidance indicates that the Plan making authority (in this case Yorkshire Water) shall adopt, or otherwise give effect to the Plan, only after having ascertained that it will not adversely affect the integrity of a European site. As such, a Stage 2 HRA was required to determine whether the implementation of the Scheme could impact on the conservation objectives or the qualifying features of the SAC, the results of which have been discussed with Natural England.

Subsequent to the completion of the Stage 2 assessment, the HRA report has been updated to include an appendix (appendix B) to provide Information to Inform the Appropriate Assessment. Available information indicates that the scheme will not, alone or in-combination with other plans or projects, have an impact on the conservation objectives or the qualifying features of the SAC. As such, the scheme will not have a significant adverse effect on the integrity of the site.

It should be noted that Yorkshire Water is undertaking a HIA and water features assessment to confirm potential impacts associated with this scheme. This scheme is not likely to be required before 2022, and any information to support the conclusions of the Appropriate Assessment and reduce uncertainty, will therefore be available before the scheme is considered. It is also important to note that this scheme has been included to improve resilience only, therefore if a subsequent assessment demonstrated a likely significant effect, alternative options within the preferred plan would be implemented to meet demand

Potential in-combination effects within the WMRP19 were assessed. The distribution management schemes would have no impact on any designated sites either alone, or in-combination with any other schemes. The R9 North Yorkshire groundwater option 1 Scheme and the R13 East Yorkshire Groundwater option 2 are located approximately 75km apart, and in-combination impacts are considered unlikely.

Cumulative assessment of the WRMP19 with other water company WRMPs, drought plans, and other relevant programmes and plans have been carried out. No in-combination impacts have been identified for any schemes within the plan or any other schemes, plans or projects within Yorkshire Water's or neighbouring water company operational areas.

10.6 Water Framework Directive Assessment of the Preferred Plan

In line with regulatory guidance, we have carried out a Water Framework Directive (WFD) assessment of the preferred solution to ensure that none of the schemes, either in isolation or in-combination, would lead to a deterioration in waterbody status.

The following objectives were set out to test for in the WFD compliance assessment:

Objective 1: To prevent deterioration between status classes of any waterbody

Objective 2: To prevent the introduction of impediments to the attainment of Good WFD status or potential for the waterbody. It is noted that for some waterbodies, it is accepted that achievement of Good status or potential is currently technically infeasible or disproportionately costly. Where this is the case, the test is applied to the currently agreed objectives for that water body rather than against Good status/potential.

Objective 3: To ensure that the planned programme of measures in the RBMP to help attain the WFD objectives for the waterbody (or the environmental objectives in the 2015 RBMPs) are not compromised

Objective 4: To ensure the achievement of the WFD objectives in other waterbodies within the same catchment are not permanently excluded or compromised.

Two further objectives were set to review and document if the option assists the meeting of WFD objectives, which is over and above a test of WFD compliance of the option:

Objective 5: To assist the attainment of the WFD objectives for the waterbody

Objective 6: To assist the attainment of the objectives for associated WFD protected areas.

The WFD assessment report has been shared with the Environment Agency and has concluded that:

- Only one scheme (R13 East Yorkshire Groundwater option 2) has the potential to lead to deterioration between classes for aquatic macroinvertebrates in the dependant surface water body. The risk of this effect requires further investigation and is currently assessed as uncertain.
- Only one scheme (R13 East Yorkshire Groundwater option 2) has the potential to introduce an impediment to the achievement of good quality status for the groundwater water body the abstraction would be from. Specifically, this relates to risk of impeding the achievement of Good status for the Saline Intrusion test (Poor status in RBMP2) and linked effects on achieving Good status for Chemical status (Poor in RBMP2). The risk of these effects requires further investigation and is currently assessed as uncertain.
- None of the options in the preferred plan, alone or in combination, impede the planned RBMP2 programme of measures to help attain WFD objectives for any water body.
- None of the options in the preferred plan, alone or in combination, affect the WFD objectives of other water bodies, beyond those uncertain risks listed above for the linked river water body, i.e. the dependant surface water body for the groundwater water body at risk from Option R13 (East Yorkshire Groundwater Option 2).
- None of the options in the preferred plan, alone or in combination, compromise the attainment of good status or good potential objectives for any waterbodies.
- None of the options in the preferred plan, alone or in combination, compromise the attainment of objectives for WFD protected areas.

10.7 SEA cumulative impact assessment of the preferred plan

A cumulative assessment of the preferred programme was undertaken to consider whether the preferred solution options, when constructed or operated together, led to additional effects on each of the SEA topics. Table 10.3 provides a summary of the SEA outputs for the preferred plan.

Most of the distribution management options included in the preferred plan are compatible, with implementation of each option increasing the overall volume of water savings made. There is a small risk that the simultaneous implementation of the distribution management schemes could lead to cumulative adverse impacts, whereby disturbance to human health, resource, and air greenhouse gas emissions could increase due to network repair and enhancement activities. However, any such cumulative impacts would be minor, as most of these activities would be localised and small in scale and could be effectively mitigated through careful project management and best practice construction methods.

There is no potential for cumulative impacts between the two resource management options included in the preferred plan, as they abstract from different aquifers. R9 North Yorkshire Groundwater option 1 boreholes abstract from the confined Millstone Grit Group aquifer, while R13 East Yorkshire Groundwater option 2 boreholes would target the Sherwood Sandstone Group aquifer.

At a plan level, cumulative effects with other relevant plans, programmes and projects were also considered. These included our Drought Plan, WRMPs and drought plans from neighbouring water companies, Environment Agency Drought Plans, Canal and River Trust Management Plans, Local Development Frameworks, National Policy Statements and National/Regional Infrastructure Plans, and major projects. No significant cumulative impacts were identified between WRMP19 and any other relevant plans, programmes and projects.

Table 10.2 SEA outputs of Grid SWZ preferred solution

Option Category	Scheme Ref.	Scheme Name	Adverse																Beneficial															
			Biodiversity, flora and fauna			Population and human health		Material assets and resource use	Water				Soil, geology and land use	Air and climate			Archaeology and cultural heritage	Landscape and visual amenity	Biodiversity, flora and fauna			Population and human health		Material assets and resource use	Water				Soil, geology and land use	Air and climate			Archaeology and cultural heritage	Landscape and visual amenity
			1.1	1.2	1.3	2.1	2.2	3.1	4.1	4.2	4.3	4.4	5.1	6.1	6.2	6.3	7.1	8.1	1.1	1.2	1.3	2.1	2.2	3.1	4.1	4.2	4.3	4.4	5.1	6.1	6.2	6.3	7.1	8.1
Distribution management	D1a-j	Increased Find and Fix	N	N	N	-	-	-	N	N	N	N	N	-	-	N	N	N	+	+	N	+++	N	+++	+	+++	N	+	N	N	N	+++	N	N
Distribution management	D4a-f	Customerside	N	N	N	-	N	-	N	N	N	N	N	-	-	N	N	N	+	+	N	+	N	+	N	+	N	+	N	N	N	+	N	N
Distribution management	D5a-f	Trunk Main Metering	N	N	N	-	N	-	N	N	N	N	N	-	-	N	N	N	+	+	N	+	N	+	N	+	N	+	N	N	N	+	N	N
Distribution management	D6a-f	DMA Engineering & PM	N	N	N	-	N	-	N	N	N	N	N	-	-	N	N	N	+	+	N	++	N	++	N	++	N	+	N	N	N	++	N	N
Distribution management	D7a-f	Acoustic Logging	N	N	N	-	N	-	N	N	N	N	N	-	-	N	N	N	+	+	N	++	N	++	N	++	N	+	N	N	N	++	N	N
Distribution management	D8a-f	Satellite Techology	N	N	N	-	N	-	N	N	N	N	N	-	-	N	N	N	+	+	N	+	N	+	N	+	N	+	N	N	N	+	N	N
Distribution management	D10a-f	Smart Networks	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	+	+	N	++	N	++	N	+	N	+	N	N	N	++	N	N
Distribution management	D11a-f	Service Pipe Renewal	N	N	N	-	N	-	N	N	N	N	N	-	-	N	N	N	+	+	N	++	N	++	N	++	N	+	N	N	N	++	N	N
Resource	R9	North Yorkshire Groundwater Option	-	N	N	N	N	-	N	N	N	N	N	-	-	N	N	N	N	N	N	+	N	+	N	N	N	N	N	N	N	+	N	N
Resource	R13	East Yorkshire Groundwater Option 2	--	--	N	-	-	N	-	--	-	N	N	-	-	N	N	N	N	N	N	+	N	N	N	N	+	N	N	N	N	+	N	N

Key	
---	Major adverse
--	Moderate adver
-	Minor adverse
N	Negligible adve
None A	No adverse effe
None B	No beneficial e
N	Negligible bene
+	Minor beneficial
++	Moderate benefi
+++	Major beneficial

10.7.1 Mitigation and monitoring

Consideration of mitigation measures has been an integral part of the SEA process. The SEA appraisals have been based on residual impacts that are likely to remain after the implementation of reasonable mitigation.

Table 11.1 in Section 11 gives a timeline of the implementation of the two resource options included in the preferred solution. This includes a period of monitoring and assessment to show when the investigations of the environmental effects would be carried out.

Where appropriate, the SEA has identified additional mitigation measures that may be required, either during the construction phase or operational phase of the resource options in the preferred solution. These mitigation measures will be further defined during the more detailed design stages of the schemes as they come forward for implementation. Mitigation measures will also be discussed as appropriate with the environmental regulators, planning authorities and English Heritage, as appropriate.

Appropriate monitoring has been identified in the SEA to track any potential environmental effects during implementation of the options, which will in turn trigger deployment of suitable and practicable mitigation measures. Prior to implementation, we will review the specific requirements for environmental monitoring in consultation with the Environment Agency, Natural England and English Heritage, as appropriate.

We will fully comply with the requirements of The Water Supply (Water Quality) Regulations 2016 Regulation 15, when considering introducing any new sources to be used ultimately for drinking water. Specifically, we will meet the arrangements stated in Drinking Water Inspectorate (DWI) Information Letter 06/2012, around providing adequate information to the DWI; appropriate sampling and monitoring; reporting requirements; following our Drinking Water Safety Planning risk assessment methodology; and submission of Regulation 28 documentation as necessary.

10.8 Scenario comparison

We considered five scenarios in determining the solution to the deficit forecast in the Grid SWZ, see Sections 9.5 and 9.7. Table 10.3 compares the costs and benefits of each scenario. We include an additional scenario in the table, which is implement our final planning scenario (preferred solution) but with further leakage reduction beyond 2025.

The costs are presented as net present value (NPV) over 100 years and include all expenditure costs, capital, operating, carbon, social and environmental. Our preferred solution will meet our long-term objective to provide our customers with a secure and sustainable water supply that will be resilient to climate change uncertainty, whilst reducing the volume we are required to take from the environment.

The initial NPV costs to implement the solution are presented with and without AMP6 expenditure. The initial leakage target reduction of 62.5Ml/d by 2019/20 is being funded from efficiency savings made in AMP6 (current period). The investment required to reduce the leakage target by a further 60Ml/d in AMP7 is included in our business plan for PR19.

Our preferred plan for WRMP19 shows a continued reduction in leakage levels to 2045. This is incorporating customer and stakeholder views on reducing demand and meets the Environment Agency's expectation for water companies to continue to reduce leakage beyond 2025. By creating a surplus in the Grid SWZ we will create additional potential benefits, such as capacity for Yorkshire Water to support the national water resilience agenda, should this be required in the future.

Leakage reduction costs beyond 2025 represent continuation of the leakage techniques we have identified to achieve the 25% reduction in leakage over AMP7. We do not expect that these activities will form the basis of our longer term leakage reduction, but they do allow for a realistic indicative cost to be presented in WRMP19. Beyond AMP7 our ambition is to continue to reduce leakage, however we assume the costs to achieve this will reduce.

As the planning period progresses, we will actively seek measures to make current leakage reduction techniques more efficient and we expect new technology to make

further reductions feasible at a lower cost. We produce WRMPs and business plans every five years and with each iteration we will review the leakage techniques available and the costs and benefits. For WRMP24 we will revise all components of the supply demand balance of the Grid SWZ, taking into account new information on the future risks and updated regulatory and customer requirements. As part of the process we will review our future leakage target in line with the supply demand balance and choose the interventions which offer the greatest value to customers, stakeholders and the environment.

Table 10.3 Grid SWZ solution scenarios comparison

Scenario	Deficit at end of planning period Ml/d	Total benefit achieved by solution Ml/d	NPV £m including AMP6 expenditure	NPV £m excluding AMP6 expenditure	% reduction in leakage target over 25 year planning period
Scenario 1: Baseline dry year annual average 25 years - LEAST COST solution	33.97	34.16	23.62	23.62	5%
Scenario 2: More extreme climate change 25 years	73.20	73.22	65.64	65.64	16%
Scenario 3: Baseline extended to a 40-year period	64.99	65.16	42.55	42.55	16%
Scenario 4: Baseline plus a 15% leakage reduction	-	43.45	52.34	52.34	15%
Scenario 4: Baseline 40% leakage reduction by AMP9	-	136.70	1489.35	1340.24	48%
PREFERRED SOLUTION 25 years (40% leakage reduction by AMP9, continued reduction to 2045 and two supply options)	-	144.70	1513.31	1364.20*	48%
PREFERRED SOLUTION excluding leakage reduction beyond 2025	-	87.39	494.47	345.36*	30%

*Preferred solution cost funded through PR19

11 Future resilience of preferred solution

Resilience is a critical aspect of the WRMP and our service to customers. Our preferred plan ensures the Grid SWZ supply demand balance will remain in surplus throughout the 25-year baseline dry year annual average scenario, the extended 40 year scenario and the more extreme climate change 25 year scenario. Implementation of the preferred solution will create a 113.17Ml/d surplus in the supply demand balance by 2044/45 and an 82.14Ml/d surplus in 2059/60.

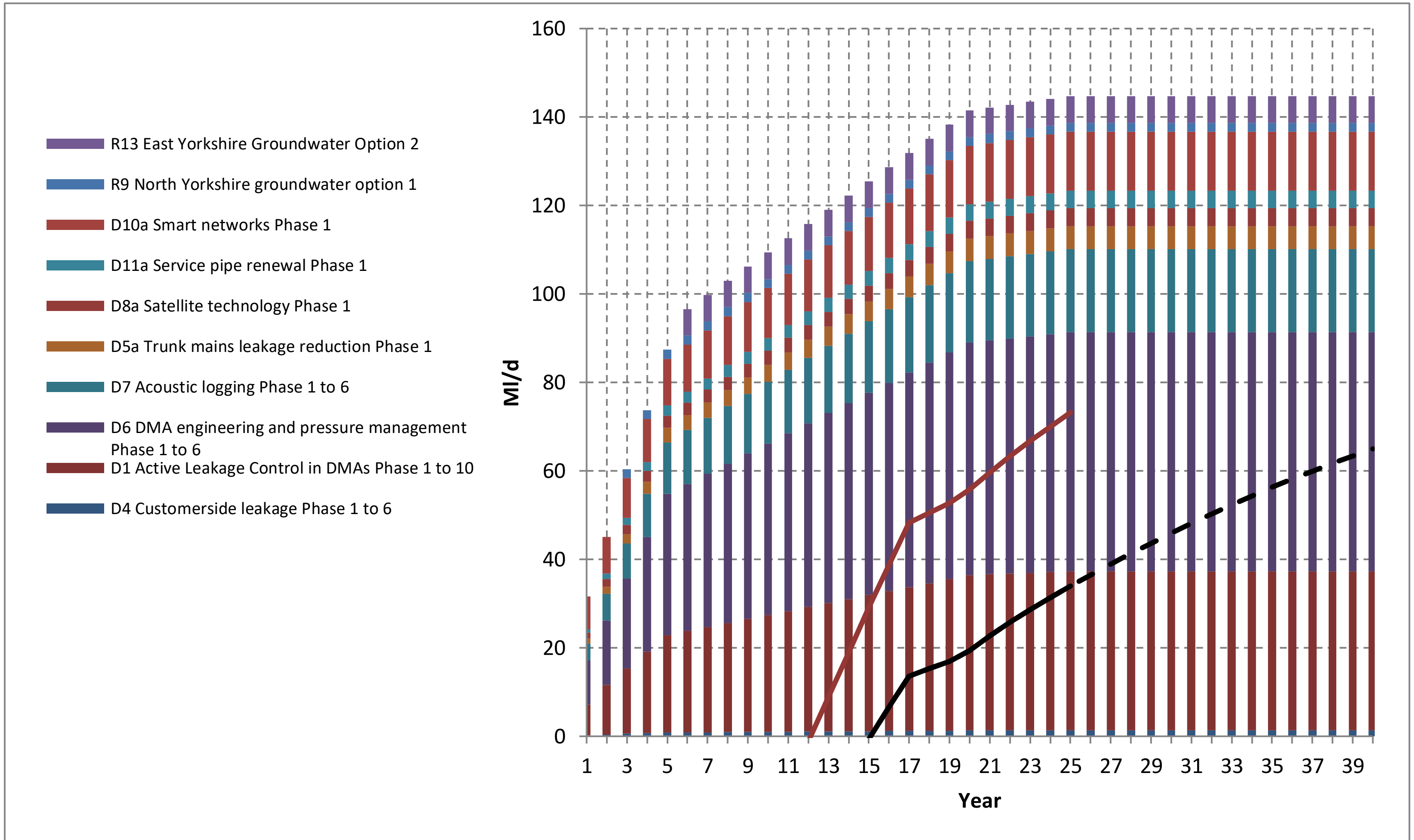
Early implementation of our leakage reduction activities will make sure we are more resilient to droughts and prepared for future sustainability reductions. There is a potential our River Derwent abstraction licence will be reduced in the near term. Investigations and options appraisals in AMP7 will clarify unknown sustainability reductions.

For this WRMP we are planning for a reduced impact of climate change compared to WRMP14 in our baseline scenario. Climate change is the biggest single influence on our long-term supply demand balance forecasts. We have tested the plan against two further scenarios, an extended 40-year planning period and an extreme climate change scenario. This helps us understand the future risks and how we might adapt to a worse case than the baseline scenario, without over planning at this stage when the impacts are still very uncertain.

To improve our understanding of climate change impacts we will use the UKCP18 climate projection data for future water resource planning and in AMP7 we will continue our investigations into climate change as discussed in Section 3.13.

The preferred solution to reduce leakage by 40% by AMP9 negates the need for investment in large new resource options to meet the deficit. The resource options that we propose to implement in AMP7 are largely for resilience and overall demand will reduce. However, in future WRMPs we could identify new risks to the supply demand balance and some of our options require further investigations to ensure they are sustainable in the longer term.

Figure 11.1 Grid SWZ preferred solution with baseline, extreme climate change and 40 -year planning period scenarios



We have two options to utilise an existing surplus licence volume on the River Ouse. This licence could provide up to 60Ml/d additional supply. The R2 Ouse Raw Water Transfer option would benefit the supply demand balance in a dry year scenario, but a more resilient solution could be to invest in additional treatment capacity at the point of abstraction, this is the R1a River Ouse water treatment works extension. This would increase the ability for transferring the water around the Grid SWZ and increase our resilience to extreme outages.

For this WRMP, we are not planning to implement either of the Ouse schemes as our preferred solution will provide us with a significant surplus. We will carry out further resilience investigations in AMP7 on the potential options to mitigate extreme outages and offset any reduction in the Severn Trent import. We are currently investigating how we will model, and potentially monetise, the value of resilience (referred to as the 'resilience dividend' by the Rockerfeller Foundation and others), with a view to incorporating this into our six capitals approach to be used in future WRMPs.

As there is potential an Ouse scheme could be required in the future, we will carry out environmental investigations alongside those required for the R9 North Yorkshire groundwater option 1 and R13 East Yorkshire Groundwater option 2 schemes which are part of the preferred plan. These investigations are outlined in Table 11.1.

Our preferred solution for the long term is to avoid reliance on increased abstraction to meet future deficits and to reduce the water we take from the environment. We will continue to investigate innovative solutions to reduce demand through further leakage reduction and other demand reduction solutions, as described in Section 6 Water efficiency and demand reduction strategy. While investment in resource schemes can help to reduce the deficit, demand reduction measures are our preference and priority because they tend to result in fewer negative impacts on natural and social capital.

Table 11.1 AMP7 environmental investigations

Potential scheme	Investigation	Driver	Timescale
R9 North Yorkshire groundwater option 1	HIA (hydrological impact assessment) – started WFD – unlikely but subject to outcomes from HRA EIA - No, licence increase	Increased risk of outages in North Yorkshire area due to housing developments in this area of the region.	AMP6 (ongoing) investigation and licence application in 2022/23.
R13 East Yorkshire Groundwater option 2	HIA - Yes WFD – Yes HRA – No EIA – No (assumed permitted development)	Water quality – will provide additional blending in an area where outages could occur due to nitrate	AMP7 investigation and licence application in AMP8 (2025/26).
River Ouse licenced abstraction (R1 or R2)	Investigation and options appraisal	WINEP	AMP7 investigation
	WFD – No HRA – No (subject to collaborative monitoring for RoC) EIA – Likely (based on outline scheme elements)	WRMP scenario testing and potential to provide additional resilience or offset an import reduction	AMP7 investigations for consideration in future WRMPs.

12 Final planning scenario supply demand balance

This section gives the final planning scenario for our WRMP19 – the surplus available with our preferred solution implemented. It describes the impact our preferred solution will have on our future leakage targets and on our carbon footprint.

Once we have implemented our preferred solution for the Grid SWZ both our water resource zones will be in surplus throughout the 25-year baseline period. The surplus is the volume available above demand plus target headroom.

12.1 PR19 Business Plan

Since publishing our draft WRMP19 we submitted our initial PR19 Business Plan to Ofwat in September 2018. In April 2019 we made some changes to the Business Plan as part of our IAP response to Ofwat. These changes include the change to the leakage projections for the 25-year planning period that have been incorporated into this final version of our WRMP19.

However, in our Final Determination of our PR19 Business Plan the leakage target is a 15% reduction by 2025. The target is also a three-year rolling average starting from the average actual leakage achieved between 2017 and 2020. This means our WRMP19 and our Business Plan include different leakage objectives and the WRMP has a more ambitious target. We will review our actual leakage annually and report progress to the Environment Agency.

Our Business Plan determines investment to maintain our services to customers over the next five years, from 2020 to 2025. In addition to the leakage projections, a number of the PR19 Business Plan schemes will impact on our supply-demand balance and this has been built into our final planning scenario.

As part of the business plan process, we have identified performance commitments we aim to achieve over the PR19 period. This includes a Recycling Performance Commitment, which has potential to reduce losses at Yorkshire Water's treatment works through additional water recycling or reduce commercial demand if we can identify solutions that are cost effective.

We are promoting water management with both household and commercial water users under our Working With Others, Per Capita Consumption and Surface Water Attenuated & Removed commitments. These performance commitments involve collaboration outside of what we can directly control on our own sites. In addition to the base water efficiency activities we discuss in Section 6.1, these performance commitments will provide rainwater harvesting through water butts and community raingardens. The Surface Water Attenuated & Removed commitment will target water efficiency activities to areas where we will trial customer water efficiency activities as a substitute to traditional measures for reducing outflow from our waste water works during dry weather.

Since publishing our draft WRMP19 we have also submitted our Drinking Water Quality programme to the DWI. This identifies investment required in the PR19 Business Plan to improve water treatment site performance or mitigate against deteriorating water quality. There are three water treatment work improvement schemes included in the Drinking Water Quality programme that have potential to impact on the outage allowance in the Grid SWZ and we have adjusted the outage assumptions for the sites in the Crystal Ball stochastic model. For each of the events the percentage loss now has a minimum value of zero, to represent the best-case scenario that no losses are experienced. The average value has been reduced by 50% of the pre-scheme values and the maximum value is unchanged, to represent that on occasion events could still result in the maximum losses previously experienced. The stochastic model has been rerun to determine the change in outage allowance and the baseline Grid SWZ total outage of 52.40Ml/d is reduced to 49.79Ml/d. The Grid SWZ final planning scenario outage has been changed to 49.97Ml/d from AMP8 onwards until the end of the planning period. The outage allowance of 52.40Ml/d has been retained for AMP7 in the final planning scenario to represent the current risk before the schemes are implemented.

The PR19 Business Plan also includes investment in our clean water distribution system to ensure we can meet demand created by new supplies in our region due to housing development. A future investment need has been identified in an area in North Yorkshire that receives its supply predominantly from a groundwater source due to plans to build up to 2,000 new houses and increased commercial use in the area. In the short term we are applying for an increase in the current licence, this is one of the boreholes mentioned in Section 3.2. In the longer term we are planning to ensure addition supply is available to the area. As this is a small, localised issue it is not apparent in the WRMP supply-demand balance assessments and a treated water solution has been identified through our business plan process. Our PR19 Business Plan has included investment in clean water distribution to install additional distribution mains to meet the demand. An alternative to this would be to further increase our licence at groundwater source and invest in additional assets (standby borehole and UV (ultra violet) treatment) at the site.

Further investigations will determine if the alternative solution is a better solution. The application to increase the borehole licence to meet the short-term needs of the area was submitted to the Environment Agency in June 2019 and at the time of writing we are awaiting determination. To support the application, we reviewed the potential solutions. In addition to the clean water main link and the increased borehole abstraction we considered demand reduction options including leakage reduction, meter enhancement and household retrofit program in the area. However, the combined benefit of these options would not be enough to secure supply in the long term.

The clean water pipeline and the increased borehole abstraction were concluded to be the only feasible long-term solutions. Both the clean water distribution option and the groundwater licence increase option have been added to our environmental impact assessments as options R62 North Yorkshire rural distribution enhancement and R63 North Yorkshire Groundwater 2.

R62 North Yorkshire rural distribution enhancement would utilise existing resource by linking the rural area to a major water treatment works in the Grid SWZ. The option would require planning permission for installing the main. R63 North Yorkshire Groundwater 2 would install an additional borehole at the existing

abstraction site and a UV disinfection unit. The option is dependent on the Environment Agency granting an increase to the permitted abstraction and on obtaining land purchase for the additional infrastructure.

The SEA of R62 North Yorkshire rural distribution enhancement identified three moderate adverse impacts relating to biodiversity, flora and fauna (associated with impacts on designated sites during construction), material assets and resource use (associated with scheme construction) and air quality (associated with scheme construction). Other minor adverse impacts, relating to biodiversity flora and fauna, population and human health, water, soil geology and land use, air and climate, archaeology and cultural heritage plus landscape and visual amenity, were also identified, relating to the scale of construction. Two minor beneficial effects were identified relating to maintaining essential public water supplies and securing a resilient water supply in the longer term to help meet the challenges of potential climate change impact on water supply reliability.

The SEA for R63 North Yorkshire Groundwater 2 identified one minor adverse effect relating to potential impacts towards the River Derwent SAC. The Habitats Regulation Assessment (HRA) identified no local significant effects (LSEs) towards the River Derwent special area of conservation (SAC). The Water Framework Directive (WFD) assessment identified no adverse effects. Three minor beneficial effects were identified relating to the provision of additional water supply to maintain the supply-demand balance, use of existing infrastructure and improving resilience towards climate change risks.

The capital cost for R62 North Yorkshire rural distribution enhancement is significantly greater than R63 North Yorkshire Groundwater 2, £14 million compared to £2 million. However, R63 is dependent on the additional abstraction volume being available and land purchase. In addition to cost we will assess the resilience benefits of the two options and if either option can be considered more sustainable over the long term.

12.2 Final supply demand balance

Table 12.1 gives the WAFU, distribution input and surplus in each zone, with the impact of the preferred solution incorporated into the Grid SWZ supply demand balance. This includes a reduction in demand due to the leakage options, increased deployable output from the two borehole schemes and a reduction in outage due to the water quality schemes included in our PR19 Business Plan.

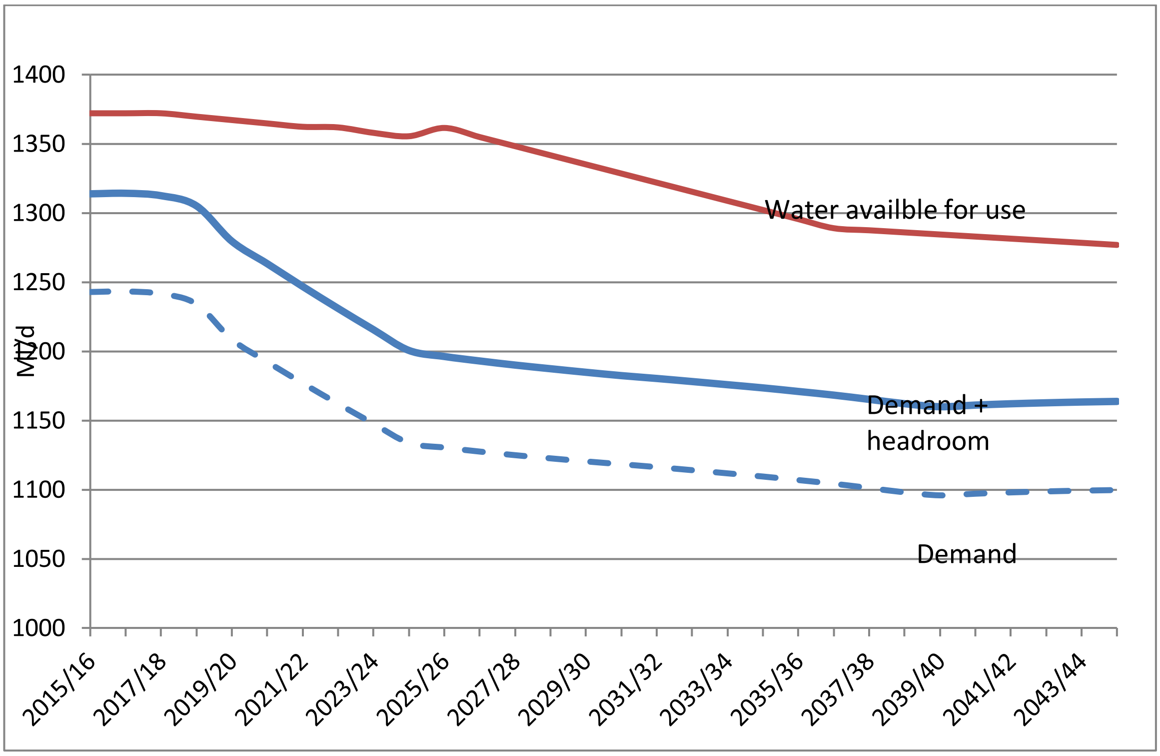
Figure 12.1 shows the Grid SWZ final planning scenario surplus over the 25-year planning period.

We have carried out WRAPsim modelling for the median climate change model ID for the final planning scenario to show that the proposed solutions will meet the supply demand deficit. This modelling shows that the preferred solution will meet the forecast deficit for the median climate change model ID. The options in the preferred solution are two ground water sources which are resilient to climate change (analysis described in our technical report on deployable output and climate change), and leakage reduction, which is also unaffected by climate change.

Table 12.1 Final planning supply demand surplus

Resource Zone Scenario	2020/21	2025/26	2030/31	2035/36	2040/41	2044/45
Grid SWZ water available for use	1364.72	1361.45	1328.51	1295.56	1282.95	1276.91
Grid SWZ distribution input	1192.32	1130.42	1118.36	1096.91	1097.02	1099.67
Grid SWZ Final planning dry year annual average surplus (Ml/d)	101.43	165.17	146.08	124.60	119.40	113.17
East SWZ water available for use	12.16	12.87	12.87	12.87	12.87	12.87
East SWZ distribution input	6.20	6.09	6.03	5.98	5.96	5.94
East SWZ dry year annual average surplus (Ml/d)	5.02	5.95	6.04	6.18	6.24	6.30

Figure 12.1 Grid SWZ final plan 25 year surplus



12.3 Final planning headroom assessment

To ensure we can be confident our preferred solution for the Grid SWZ will meet the forecast deficit we must consider if there is any risk the selected options may not achieve the defined benefit. If there is a risk further headroom allowance is built into the Grid SWZ final planning scenario. We must then invest in additional options or find an alternative solution to remove the risk.

Our preferred plan is to reduce the base year regional leakage by 40% in AMP9 (176Ml/d by 3022/23) and to continue to reduce further to a level of 150Ml/d by 2045. We also plan to implement two resource management options. This results in the Grid SWZ supply demand balance being in surplus by more than 100Ml/d throughout the 25 year planning period

The leakage reduction schemes will introduce new and emerging techniques into our traditional find and fix leakage reduction activities. This carries a level of risk that the associated savings may not be achieved. However, as the deficit in the 25 year plan starts at 6.49Ml/d in 2035/36 and increases to 33.97Ml/d by 2044/45 it is significantly below the surplus created by our preferred solution. Therefore, we have

not built any uncertainty for the solution not meeting the deficit into the final target headroom allowance.

We have set a target to reduce the base line leakage by 40% by AMP9. This means the options will be implemented early in the planning period before the forecast deficit in 2035/36. We therefore have additional security in that, if there is any shortfall, we would be able to address this in future planning cycles of the WRMP. The final planning target headroom is the same as the baseline headroom as shown in Tables 12.2. The available headroom for the Grid SWZ final planning scenario is at the 95th percentile in 2020/21 reducing to the 70th percentile by 2044/45.

Table 12.2 Final plan target headroom

	2020/21	2025/26	2030/31	2035/36	2040/41	2044/45
East SWZ final plan dry year annual average						
Target headroom certainty percentile	95th	90th	85th	80th	75th	70th
Target headroom Ml/d	0.94	0.83	0.80	0.71	0.67	0.63
Target headroom % of WAFU	7.7	6.8	6.5	5.8	5.5	5.1
Available headroom Ml/d	5.96	6.07	6.13	6.18	6.20	6.22
Available headroom percentile	100th	100th	100th	100th	100th	100th
Available headroom % of WAFU	49.1	50.0	50.5	50.9	51.1	48.9
Grid SWZ final plan dry year annual average						
Target headroom certainty percentile	80th	70th	55th	-	-	-
Target headroom Ml/d	70.97	65.86	64.07	64.07	64.07	64.07
Target headroom % of WAFU	5.4	5.1	5.2	5.4	5.4	5.4
Available headroom Ml/d	172.40	231.03	210.15	186.67	185.93	177.24
Available headroom percentile	95th	95th	90th	75th	75th	70th
Available headroom % of WAFU	13.1	17.6	16.4	15.1	15.1	14.4

12.4 Future leakage targets

Table 12.4 gives the final planning scenario regional leakage targets, incorporating additional leakage reduction in the Grid SWZ, through DMA optimisation and pressure management, trunk mains leakage activity, supply pipe leakage and new leakage detection activities.

The regional leakage target reduces significantly from our current target of 297.1Ml/d in 2017/18 to 169.7 by the end of AMP9. This will achieve the 40% leakage reduction and we plan to continue to decrease leakage for the remainder of the planning period.

Table 12.3 Future leakage targets

	AMP6		AMP7					End AMP11
Future Leakage Targets (Ml/d)	**2018/19**	**2019/20**	**2020/21**	**2021/22**	**2022/23**	**2023/24**	**2024/25**	**2044/45**
Cumulative leakage reduction (Ml/d)	21.1	62.5	92.1	98.8	106.6	114.3	122.0	146.6
Leakage Target	292.1	269.0	255.5	242.1	228.7	215.3	201.8	150.4

12.5 Water efficiency target

For every WRMP we set a water efficiency target for the next five year (or AMP) period. For the period 2020/21 to 2024/45, referred to as AMP7, we are linking our water efficiency target to the weighted average PCC calculated in WRMP19.

As discussed in Section 4.4.1 the average household PCC is forecast to decline due to an increasing proportion of measured households (with associated lower PCC), increasing water efficient behaviour and use of water efficient appliances.

The water efficiency activity we describe in Section 6 to reduce household customer water use has been built into our demand forecast and contributes to the PCC projections.

In previous AMP periods, we have defined a target volume to achieve through water efficiency activity. For AMP7 we propose to use our water efficiency activity as a measure to achieve our PCC performance commitment in the PR19 Business Plan.

Table 12.4 AMP7 water efficiency activity and estimated savings

Activity	Savings litres per property	Number of properties per year	Assumed total annual saving Ml/d		
			Lower	Mid	Upper
Free self-fit water saving packs	3 to 7	10,000	0.03	0.05	0.07
Visit and fit – home audit and retrofit	15 to 45	2,000	0.03	0.06	0.09
Total savings 2020 to 2025			0.3	0.6	0.8

The water efficiency activity we propose to deliver to household customers between 2020 to 2025 is summarised in Table 12.6. It is difficult to accurately measure the savings as it is dependent on customer uptake to the initiatives offered and the potential benefits can vary from property to property. We have applied a range of potential savings our free water saving packs and home audit visit and fit services could achieve in AMP7. This is based on our own analysis of water savings and learning from other water companies.

For AMP7 we will set a target to deliver these services to the number of properties as defined in Table 12.4 to help achieve our forecast PCC values. In addition to this we will continue to implement our customer behaviour campaign to target customers

with relevant messages that will advise on behaviour change water saving measures and help develop our visit and fit service.

Our proposed pilot projects for new housing settlements and commercial sub potable use will inform us on how we can work in partnership to deliver water efficiency in the future. This will help shape our water efficiency target in the next WRMP.

12.6 Greenhouse gas emissions

The Defra *Water Resources Management Plan Direction 2017* requires water companies to produce a description of "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)" of the Water Industry Act 1991.

We have forecast the total regional greenhouse gas emissions (tonnes of CO_2 equivalent) for regional water production in each year of the planning period for the baseline scenario and the final planning scenario. This is presented in Figure 12.2 and includes emissions for both the East SWZ and Grid SWZ.

Figure 12.2 Baseline and final planning scenario regional greenhouse gas emissons

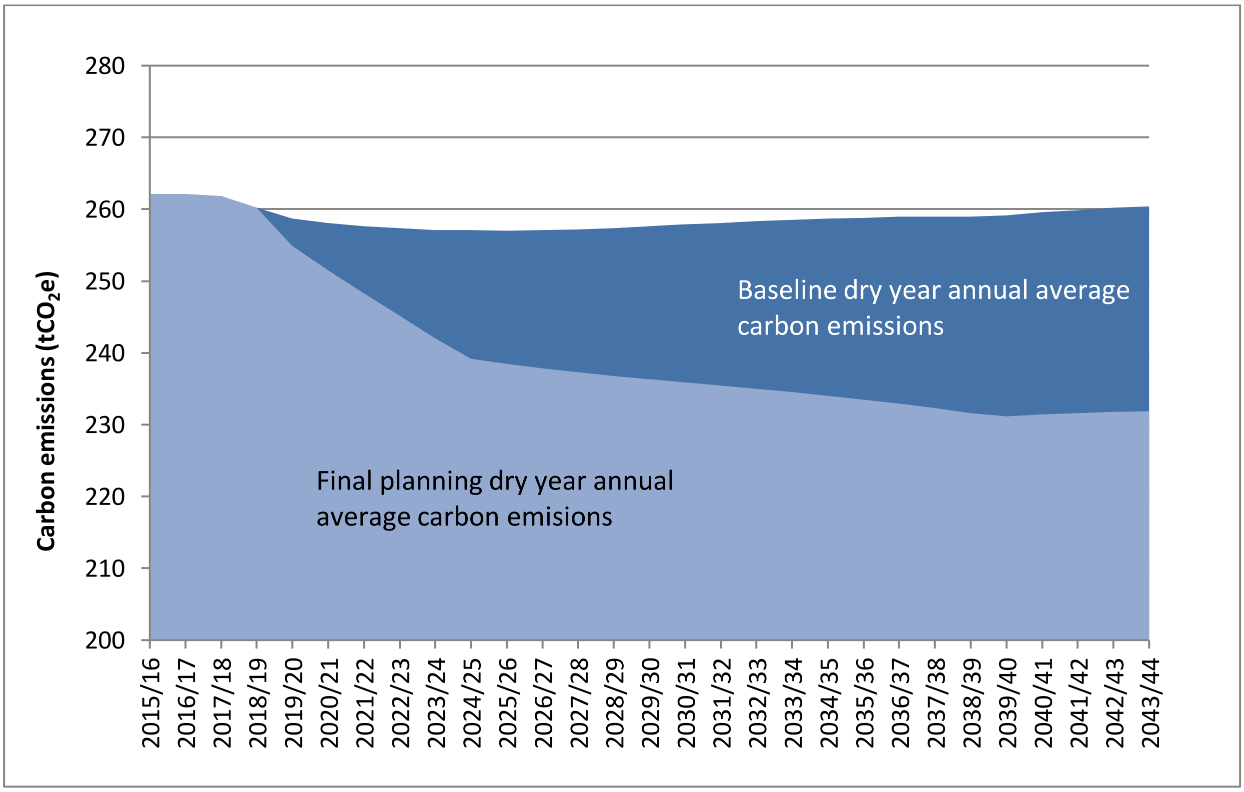


Figure 12.2 shows greenhouse gas emissions reduce in the final planning scenario. This is due to the demand reduction schemes reducing the average daily volume of water we need to abstract and distribute in the Grid SWZ. Although the new resource scheme could provide additional emissions these are only likely to be used in response to outages or peak demands and the emissions are overridden by demand reduction.

The greenhouse gas emissions for operating each of the options we will implement as part of our preferred solution are provided in Table 12.5.

Table 12.5 Greenhouse gas emissions to deliver the Grid SWZ preferred solution after implementation

Ref.	Option	Average greenhouse gas emissions per Ml/day (t CO_2e)
D1a - D1k	Find and fix active leakage control phase 1 to 11	1.13
D4a – D4f	Customer side - stop-taps and AMR alarms phase 1 to 6	-0.21
D5a – D5f	Trunk mains losses phase 1 to 6	-0.21
D6a – D6f	DMA engineering and pressure management phase 1 to 6	-0.21
D7a – D7d	Acoustic logging phase 1 to 4	-0.21
D8a – D8f	Satellite technology phase 1 to 6	-0.21
D10a – D10c	Smart networks phase 1 to 3	-0.21
R9	North Yorkshire Groundwater Option 1	0.28
R13	East Yorkshire Groundwater Option 2	0.80

13 List of tables

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15 Bibliography

Artesia Consulting, 2017, Yorkshire Water WRMP19 Household Consumption Forecast

Arup, 2013, Yorkshire Water AMP5 PR14 Water Resources Options

Cascade, 2012, Strategic Environmental Assessment of the Water Resources Management Plan

CEH, 2016, https://www.ceh.ac.uk/news-and-media/blogs/flood-science-developments-following-uk-201516-winter-floods, last viewed 1/12/17

CIEEM, CIRA, IEMA, 2016, Biodiversity Net Gain: Good practice principles for development

CLG, 2007, Code for Sustainable Homes

Cochran, W, Sampling Techniques 3rd ed, 1977, Chapter 5, Further aspects of stratified sampling, The construction of strata

Committee on Climate Change, 2017, UK Climate Change Risk Assessment

DECC, 2012, A brief guide to the carbon valuation methodology for UK policy appraisal

DECC, 2015, Updated short-term traded carbon values used for modelling purposes

Defra, 2009, UKCP09: UK Climate Change Projections

Defra, 2011, Biodiversity 2020: A strategy for England's wildlife and ecosystem services

Defra, 2012, Water White Paper – Water for Life

Defra, 2016, Creating a great place for living. Enabling resilience in the water sector

Defra, 2017, The Government's strategic priorities and objectives for Ofwat

Defra, 2017, The Water Resources Management Plan (England) Direction 2017

Department of the Environment, 1996, Water resource and supply: agenda for action

Downing, T.E. et al, 2003, CCDEW: Climate Change and the Demand for Water

Drinking Water Inspectorate, 2017, Guidance Note: Long term planning for the quality of drinking water supplies

Edge Analytics, 2016, Population, Household & Property Forecasts

Edge Analytics, 2017, Yorkshire Water Clandestine and Hidden Populations

Eftec, 2012, Benefits Assessment Guidance (report for Environment Agency)

Environment Agency, 1997, Re-assessment of Water Company Yields.

Environment Agency, 2013, Climate change approaches in water resources planning – overview of new methods

Environment Agency 2015, Understanding the performance of water supply systems during mild to extreme droughts Report – SC120048/R

Environment Agency, Natural Resources Wales, 2017, Water Resources Planning Guideline: Interim update

Environment Agency, 2017, Water industry strategic environmental requirements (WISER) Strategic steer to water companies on the environment, resilience and flood risk for business planning purposes

Environment Agency and Natural Resources Wales, 2013, Water Stressed Areas – Final Classification

HR Wallingford, 2012, UKCP09 Climate Change Scenarios in Water Resource Planning: Developing an approach for Yorkshire Water- Summary of Approach

Ministry of Housing, Communities & Local Government, 2018, National Planning Policy Framework

Mott MacDonald, 2012, YWS Climate Change Trends: Climatic Change Evidence and Trend Analysis for Yorkshire

National Infrastructure Commission, 2018, National Infrastructure Assessment

National Infrastructure Commission, 2018, Preparing for a drier future: England's water infrastructure needs

Nera, 1998, The Environmental and Social Value of Leakage Reduction

ODPM, 2005, A Practical Guide to the Strategic Environmental Assessment.

Ofwat/RPS, 2008, Providing Best Practice Guidance on Inclusion of Externalities in the ELL Calculation

Ofwat, 2016, Eligibility guidance on whether non-household customers in England and Wales are eligible to switch their retailer

Ofwat, 2017, Delivering Water 2020: Consulting on our methodology for the 2019 price review

Prudhomme, C., Crooks, S., Jackson, C., Kelvin, J., Young, A., 2012, Future flows and groundwater levels. Final technical report.

RPA, 1998, The Environmental Costs and Benefits of Water Resources: A Preliminary Methodology. (Prepared on behalf of the Environment Agency)

RPS Water, 2008, Ofwat, Environmental Economics Consultancy: Leakage Methodology Review Project, Providing Best Practice Guidance on the Inclusion of Externalities in the ELL calculation

Route2, 2017, Non-Household Water Demand Forecasting

SMC, 2012, Review of the calculation of sustainable economic level of leakage and its integration with water resource management planning, report for Environment Agency, Ofwat, Defra

Turner and Townsend, 2016, Whole Life Cost Assessment Guidance Document: Supporting Asset Management and the wider Yorkshire Water business in the standardised assessment of Whole Life Cost and Carbon

Uff J, Mawer P, Herrington P, 1996, Water supply in Yorkshire. Report of the independent commission of inquiry

UKWIR, 1995, Outage Allowances for Water Resource Planning

UKWIR,1999, Estimating Legitimate Non-Household Night Use Allowances

UKWIR/Environment Agency, 2000, A Unified Methodology for the Determination of Deployable Output from Water Sources

UKWIR, 2002, A Re-evaluation of the Methodology for Assessing Headroom

UKWIR, 2002, The Economics of Balancing Supply and Demand (EBSD) Guidance

UKWIR, 2009, Factors affecting the Natural Rate of Rise of Leakage

UWKIR, 2011, Best practice for the derivation of cost curves in economic level of leakage

UKWIR, 2012, Water Resources Planning Tools

UKWIR, 2012, A Framework for Accounting for Embodied Carbon in Water Industry Assets (12/CL/01/15)

UKWIR, 2012, Strategic Environmental Assessment and Habitats Regulation Assessment Directive.

UKWIR, 2012, Impact of Climate Change on Demand Main Report (13/CL/04/12)

UKWIR, 2013, Economics of Supply Pipe Leakage

UKWIR, 2013, Resilience planning: good practice guide

UKWIR, 2014, Handbook of source yield methodologies

UKWIR, 2015, WRMP19 methods – Household Consumption Forecasting (Report ref. 15/WR/02/9)

UKWIR, 2015, Leakage Upstream of District Meters

UKWIR, 2016, Factors Affecting Minimal Achieved Levels of Leakage

UKWIR, 2016, Population, household property and occupancy forecasting

UKWIR, 2016, Integration of behavioural change into demand forecasting and water efficiency

UKWIR, 2016, WRMP 2019 Methods – Decision Making Process: Guidance

UKWIR, 2016, WRMP 2019 Methods - Risk Based Planning: Guidance

UKWIR, 2017, Consistency of Reporting Performance Measures (Report Ref. 17/RG/04/5)

UKWIR, 2018, Climate Change and the WRMP

URS Scott Wilson and CCRM, 2011, Climate Change Risk Assessment, Phase 1: Impact and Vulnerability Assessment

Water UK, 2016, Long Term Water Resources Planning Framework

WRc and Stone and Webster, 2003, Future approaches to leakage target setting for water companies in England and Wales: an investigation by WRc with Stone and Webster Consultants for the Tripartite Group of the Department for Environment, Food and Rural Affairs, the Environment Agency and Ofwat (The Tripartite Report)

WRc, 2012, Duration Modelling - impact of multi-year drought events on resources and assets

WRc, 2012, Water Consumption of Homes Built to Part G and Code for Sustainable Homes Standards

16 Glossary of terms

AISC	Average Incremental Social Cost
AMP	Asset Management Period (5-year price review period)
AMP6	Planning period 2015-16 to 2019-20
AMP7	Planning period 2020-21 to 2024-25
BRE	Building Research Establishment
BL	Background leakage

CAMS Environment Agency’s Catchment Abstraction Management Strategies (local licensing strategies that set out how water resources will be managed within a catchment area)

CCP	Constraint Challenge Process
COPI	Construction Output Prices Index
CROW Act	Countryside and Rights of Way Act 2000
DCL	Drought Control Line
DCM	Domestic Consumption Monitor
Defra	Department for Environment, Food and Rural Affairs

DMA Distribution Management Area - Yorkshire Water leakage control zone (also known as District Metered Area)

DO	Deployable Output
DWI	Drinking Water Inspectorate
EA	Environment Agency

ELL Economic level of leakage

GCM Global Circulation Models

GWZ Groundwater Zone (Environment Agency Water Resource Zone)

HOF Hands Off Flow licence conditions that require abstraction to cease (or reduce) when river flows fall below a specified level

HRA Habitats Regulations Assessment

KAMS Key Asset Management System – Yorkshire Water asset reporting system

l/h/d Litres per head per day

LoS Level of Service

Ml/d Mega litres per day

MLE Maximum Likelihood Estimation

MSL Marginal Storage Line

NCL Normal Control Line

NEP National Environmental Program

NPC Net Present Cost

NPV Net Present Value

Ofwat Water Services Regulation Authority

PCC Per Capita Consumption

PMZ Production Management Zone – Yorkshire Water operational planning zone

PR14 Price Review submission to Ofwat 2014

SDS Strategic Direction Statement

SEA Strategic Environmental Assessment

SELL	Sustainable economic level of leakage
SRO	Source Reliable Output
SSSI	Site of Special Scientific Interest
SWZ	Surface Water Zone (Environment Agency Water Resource Zone)
TLL	Time Limited Licence
UKCP09	United Kingdom Climate Projections 2009
UKCP18	United Kingdom Climate Projections 2018
WAFU	Water Available For Use
WFD	Water Framework Directive
WINEP	Water Industry National Environment Programme
WRAP	Water Resources Allocation Plan (water supply network model)
WRAPsim	Water Resources Allocation Plan simulation (water network simulation model)
WRIO	Water Resources Investment Optimiser
WRZ	Water Resource Zone
WTP	Willingness to Pay Survey
YWS	Yorkshire Water Services Limited

17 Appendices

17.1 Appendix A.1: Yorkshire Water unconstrained list of options

Table 17.1 Unconstrained list of options

Reference	Option Scheme Name	Feasibility
Customer side management		
C1a – C1e	Domestic customer audits and retrofit, 5 phases	Feasible
C2	Metering - domestic meter optants	Feasible
C3	Compulsory Metering	Constrained out - Yorkshire not a water stressed area
C4	Metering on change of occupancy	Feasible
C5	Smart Metering	Feasible
C6a – C6e	Commercial water user audits and retrofit – Yorkshire Water pays, 5 phases	Feasible
C7a – C7e	Commercial water user audits and retrofit - customer pays, 5 phases	Constrained out – no certainty customers would agree to participate
C8	Business Customer supply pipe leakage/plumbing loss reduction	Constrained out – service is under control of commercial retailers. Savings can vary greatly from year to year and there is no certainty savings can be made above those already achieved.
C9	Greywater supply to domestic customers	Constrained out – Dependent on partnership opportunities e.g. housing developers and pilot schemes. Potential pilot studies identified for AMP7.
C10	Greywater supply to industrial customers	Constrained out – Dependent on partnership opportunities e.g. commercial water users able to rely on non-potable water. Potential pilot studies identified for AMP7.

C11	Rainwater harvesting for domestic customers	Constrained out – could be considered alongside greywater use through partnerships with housing developers if pilot studies identified.
C12	Rainwater harvesting for commercial customers	Constrained out – this activity has been delivered in our region in the past and is dependent on commercial user's uptake.
C13	Tariffs/special fees	Constrained out – insufficient data to form a reliable scheme
Distribution side management		
D1a to D1j	Active Leakage Control (in DMAs) – find and fix	Feasible
D2a – D2c	Pressure management (leakage reduction), 3 phases	Combined with DMA engineering as D6
D3	Mains replacement	Constrained out – still considered in business planning for reducing bursts but cost benefit assessment concluded not a feasible option for reducing leakage target.
D4a – D4f	Customer side Supply pipe leakage reduction - monitoring stop-taps and AMR alarms	Feasible
D5a – D5f	Trunk mains losses	Feasible
D6a – D6f	DMA engineering and pressure management	Feasible
D7a - D7d	Leakage detection - acoustic logging	Feasible
D8a – D8f	Leakage detection – satellite technology	Feasible
D9a – D9f	Data improvement	Constrained out – this option aims to improve data used in leakage calculations through more trials and data validation. It was previously a feasible option and part of the solution for the draft WRMP19. We will continue to improve our data however, it is no longer an individual option as its benefits will be linked to the other leakage options.
D10a - D10f	Smart networks	Feasible

D11a – D11f	Service pipe renewal	Feasible
D12	Supply pipe leakage reduction - External DMO meters	Constrained out due to uncertain benefit and high cost to benefit ratio
Production management		
P1	Reduction in WTW process losses Option 1	Feasible
P2	Reduction in WTW process losses Option 2	Feasible
P3	Reduction in WTW process losses Option 3	Feasible
P4	Reduction in WTW process losses Option 4	Feasible
Resource Management		
R1a	River Ouse water treatment works extension Option 1 – 45Ml/d maximum	Feasible
R1b	River Ouse water treatment works extension Option 2 – 95Ml/d maximum	Constrained out - risk of over-abstraction from river
R2	Ouse Raw Water Transfer	Feasible
R3	Increased River Ouse pump storage capacity	Feasible
R4	Rural Aquifer Storage & Recovery	Constrained out – no locations identified
R5	Aquifer Storage and Recovery Scheme 1	Feasible
R6	South Yorkshire Groundwater Option 1	Feasible
R7	Doncaster - River Water Recharge	Constrained out – unlikely to provide water
R8a	Sherwood Sandstone and Magnesian Limestone Boreholes option 1	Constrained out – river argumentation scheme uncertain, scheme details to be reviewed for future WRMP submissions
R8b	Sherwood Sandstone and Magnesian Limestone Boreholes option 2	Constrained out – river argumentation scheme uncertain, scheme details to be reviewed for future WRMP submissions
R9	North Yorkshire Groundwater Option 1	Feasible
R10	Millstone Grit Groundwater Option	Constrained out – no location identified
R11	South Yorkshire Groundwater Option 1	Constrained out – South Yorkshire Groundwater option 1 is a more reliable use of these boreholes
R12	East Yorkshire Groundwater Option 1	Feasible
R13	East Yorkshire Groundwater Option 2	Feasible

R14	Minewater for potable use	Constrained out - water quality cannot be assured for potable water supply. Potential for non-potable use in future WRMPs if water users interested.
R15	Reuse of Abandoned Yorkshire Water groundwater sources	Constrained out – will be considered in R8 review for future WRMPs
R16	Reuse of Abandoned Groundwater Sources Option 1	Feasible
R17	Reuse of Abandoned Groundwater Sources Option 2	Feasible
R18	Reuse of Abandoned Groundwater Sources Option 3	Feasible
R19	Reuse of Abandoned Groundwater Sources Option 4	Feasible
R20	Embankment raising 1	Constrained out - Technical difficulties raising earth embankments
R21	Dam Raising Option 1	Feasible
R22	Dam Raising Option 2	Constrained out - Engineering constraints
R23	Dam Raising Option 3	Feasible
R24	Dam Raising Option 4	Feasible
R25a	Embankment raising 2	Constrained out - Technical difficulties raising earth embankments
R25b	Embankment raising 3	Constrained out - Within an area of outstanding natural beauty
R26	Reservoir catchment increase	Constrained out - Yield uncertain and would be low (under 1Ml/d)
R27	Reservoir extension	Constrained out – high environmental impacts for low yield and stakeholder objections
R28	Extend reservoirs sideways	Constrained out – Insufficient information
R29	Reservoir desilting	Feasible
R30	Use compensation reservoirs as supply	Constrained out – Uncertain yield
R31	River abstraction and bankside storage on the River Wharfe	Constrained out – High number of objections and environmental impacts
R32	Swale new pumped storage reservoir	Constrained out – High number of objections and environmental impacts

R33	Storage on the River Hull	Constrained out – Low yield and potential impact on SSSI
R34	River Calder abstraction option 1	Feasible
R35	River Aire abstraction Option 1	Feasible
R36	River Aire abstraction Option 2	Constrained out – requires pipeline through built up area, alternative River Aire options more feasible.
R37	River Aire abstraction Option 3	Feasible
R38	River Trent river abstraction and bankside storage	Constrained out – No water available for new abstractions
R39	River Abstraction – Lower Don	Constrained out – Water quality impacting environment and conflicts with local power station water use
R40	Reservoir supported abstraction from the River Wharfe	Constrained out – High number of objections from stakeholders
R41	Increase existing river and GW abstractions.	Individual schemes identified – R8 and R34 to R40
R42	Improve grid connectivity	Individual schemes identified – R2, R6, R7
R43	East Yorkshire internal transfer 1	Constrained out – no water resource benefit
R44	East Yorkshire internal transfer 2	Constrained out – no water resource benefit
R45	Dales pipeline connection	Constrained out – no water resource benefit
R46	Tankering to isolated rural areas	Constrained out – short term drought/emergency option only, not a long-term solution
R47	Reduce outage	A number of options will mitigate outage risks - see section 9.1.4
R48	Reduce current level of service e.g. temporary use bans 1:10 years	PR19 willingness to pay studies demonstrated customers unwilling to accept a lower level of service
R49	Supply Dales from the Tees – raw 1	Feasible
R50	Supply Dales from the Tees - raw 2	Feasible
R51	Supply Dales from the Tees - treated	Feasible

R52	Tees - Wiske Transfer Scheme	Constrained out – Not viable to transfer to Wiske
R53	Tees - Swale River Transfer Option 1	Constrained out – pipeline preferred solution due to environmental impacts
R54	Tees - Ouse Pipeline Option 1	Feasible
R55	Tees – Swale River Transfer Option 2	Constrained out – pipeline preferred solution due to environmental impacts
R56	Tees - Ouse Pipeline Option 2	Feasible
R57(i)	Transfer from United Utilities Option 1	Constrained out – required canal for transfer and Canal and Rivers Trust interested in the same potential supply
R57	Transfer from United Utilities Option 2	Constrained out – uncertain benefit in dry year
R58	Transfer from United Utilities Option 3	Feasible
R59	Transfer from United Utilities Option 4	Feasible
R60	Third party transfers/trading	Specific schemes identified – R14, R49, R50, R52 to R54, R57 to R59
R61	East Yorkshire coast desalination	Feasible
R62	North Yorkshire rural distribution enhancement	Feasible
R63	North Yorkshire Groundwater 2	Feasible
R64	Utilise a tidal barrage at Hull	Constrained out – environmental concerns in the Humber Estuary
R65	River Ure Gravel Pits	Constrained out – no locations identified
R66	Use of canal water	Constrained out – no locations identified
R67	Effluent reuse	Constrained out – no yield gain for Yorkshire Water
R68	Dewatering of national rail tunnels	Constrained out – poor water quality and uncertain yield
R69	Infiltration galleries	Constrained out – no certainty of yield and likely to be low
R70	Link desalination to energy waste	Constrained out – no location identified
R71	Work with Internal Drainage Boards to increase abstractions	Constrained out – uncertain yield and conflicts with agricultural use
R72	River Wharfe licence increase	Feasible

R73	River Derwent licence increase	Constrained out – the River Derwent is under review as part of a Habitats Directive investigation

17.2 Appendix A.2: Yorkshire Water feasible options

Customer side management options

C1 Domestic customer audits and retrofit

This scheme aims to reduce customer use through installing retrofit devices, such as cistern devices, aerated showerheads and aerated tap inserts, in domestic properties. We estimate a 1Ml/d saving could be achieved through fitting devices in 65,500 properties over five years. We have assumed a five year half-life of savings. The scheme can be delivered in phases (C1a to C1e) each phase saving 1Ml/d over a five year period.

C2: Metering (domestic meter optants)

This scheme aims to increase the number of meter optants by an additional 25,000 above those planned in the baseline forecast. We estimate this scheme will reduce water consumption by 0.34Ml/d after a five year implementation period.

C4: Metering on change of occupancy

A meter would be installed in unmeasured households on change of occupancy during house moves. The option has been calculated for change of occupancy over 25 years divided into five phases, allowing for reduced benefits each five year period as more properties become metered. We estimate demand would reduce by 25Ml/d on full implementation.

C5: Smart metering on change of occupancy

Yorkshire Water domestic customers paying for a metered supply currently have automatic meter reading (AMR) meters installed. This option is a 20 year programme to convert all domestic meters to smart meters. It is divided into four phases with total savings of 31.7Ml/d on full implementation. The earliest start date would be 2025 when existing meters reach the end of their asset life.

C6 Commercial water use audit and retrofit

This scheme will deliver water efficiency to business customer premises across Yorkshire. Based on a trial in our region, this scheme plans to achieve a saving of 1Ml/d through auditing and retrofitting businesses over five years. We have

assumed a five year half-life of savings. The scheme can be delivered in phases (C6a to C6e) each phase saving 1Ml/d over a five year period.

Distribution management options

D1: Active leakage control - Find and fix

D1: Increase leakage reduction through enhanced find and fix activity. This will include employing more leakage detection and analytical staff. It will enable us to identify and fix more leaks each year and within shorter timescales, thereby reducing the annual leakage total. The scheme is divided into 10 phases, with total savings of 35.94Ml/d, to allow flexibility in the selection of this option.

D4: Customer side Supply pipe leakage reduction - monitoring stop-taps and AMR alarms

This scheme is to achieve water savings through identifying and repairing domestic customer supply pipe leaks. Several techniques will be used to identify continuous flows on customer properties including stop tap monitoring and use of AMR alarms. The customer will be notified of the potential leak and we will offer a leakage repair service where, with the customer's agreement, a technician will visit the property to identify the leak location and make repairs. The scheme is divided into six phases with total savings of 1.37Ml/d.

D5: Reduce trunk mains losses

Reductions in distribution input could be achieved through identifying and repairing leaks on trunk mains i.e. large capacity pipes transferring water from our water treatment works to DMAs. Water balance calculations would be required to identify potential trunk mains which could be leaking. Leakage engineers can then detect and repair the leaks. This scheme is divided into six phases achieving 5.23Ml/d in total.

D6: DMA engineering and pressure management

DMA optimisation reduces leakage by intensive investigation by our skilled engineers, which either finds a very small number of significant large volume leaks or sets DMAs up to remove anomalies and enable more effective DMA targeting. We have included two types of DMA optimisation, DMA engineering and DMA resizing. For many of our DMAs these techniques are combined with pressure management to achieve the most benefit. This scheme is divided into six phases achieving 53.98Ml/d in total.

D7: Acoustic logging

Acoustic logging in DMAs would reduce leakage through more rapid identification of leaks compared to traditional find and fix activity. This scheme aims to install acoustic loggers in DMAs where analysis indicates a higher than average rate of rise. This scheme is divided into four phases achieving 18.84Ml/d.

D8: Satelite technology

This option is similar to D7 above but uses satellites to detect leaks in less time than traditional find and fix activity. This scheme is divided into 6 phases to achieve 4.06Ml/d total savings.

D10 Smart networks

Reduce leak run time and the volume lost per leak by analytics to reduce awareness and detection time. This may require additional data logging. This scheme is divided into six phases to achieve 13.41Ml/d.

D11 Service pipe renewal

This is option is to reduce the volume of water lost each day through leaks on pipes that connect our mains to customers' individual properties. We already offer a leakage repair service but in some cases more water could be saved through replacing the pipes. The scheme is divided into six phases to achieve 3.87Ml/d.

Production management options

P1a and P1d: Reduce water treatment works process losses

We have identified four water treatment works in the Grid Surface Water Zone where water lost during the treatment process could be reduced through installing more efficient infrastructure.

Resource management options

R1a: River Ouse water treatment works extension

This scheme involves extending an existing water treatment works in York to provide an additional 22Ml/d on average. This would utilise the same existing licence on the River Ouse as R2. We would only implement one of the two schemes.

R2: Ouse Raw Water Transfer

The scheme would abstract up to 60Ml/d of raw water from the River Ouse for treatment near York. Constraints in the Grid SWZ limit the volume that can be used in supply. This volume is partly dependent on other schemes being developed and we estimate 40Ml/d would be available. The scheme requires construction of a new river intake, pumping station and pumping main from the point of abstraction to the point of treatment.

R3: Increased River Ouse pumped storage capacity

The scheme involves construction of a new transfer main and pumping station between the River Ouse and a nearby water treatment. The scheme could be used to maximize an existing abstraction licence on the Ouse. This is not the same Ouse licence as R1 and R2 and this scheme could be delivered independently. We estimate it would provide an additional 10Ml/d.

R5: Aquifer Storage and Recovery Scheme 1

This scheme involves the use of new pumped boreholes to artificially 'recharge' the Sherwood Sandstone aquifer, allowing the use of this water supply during drier periods. We estimate the average yield of the artificial recharge would be 10Ml/d.

R6: South Yorkshire groundwater scheme

A potential 12Ml/d of yield can be attained from an underutilised group of groundwater sources in South Yorkshire. A short length of pipeline would be required to link the sources to the grid system for internal transfer.

R9: North Yorkshire Groundwater option 1

This scheme involves applying for an increase to an existing groundwater abstraction licence in North Yorkshire. This would increase yield by 2Ml/d.

R12: East Yorkshire groundwater option 1

Up to an additional 8Ml/d yield is estimated to be available from an existing licenced groundwater group in East Yorkshire. This scheme would enhance the existing pumping capacity of existing infrastructure to transfer additional water from the boreholes to the grid system.

R13: East Yorkshire groundwater option 2

This scheme proposes to relocate an existing borehole in the East Yorkshire area to replace the yield lost from an asset that is no longer in use due to water quality issues. A licence variation on the existing abstraction would be required. This source could provide the grid system with up to 6Ml/d annual average (9Ml/d peak) although in the dry year scenario the total yield may not be required. However, it would provide support to the East Yorkshire borehole group when outages occur.

R16 to R19: Re-use abandoned industrial licences Options 1, 2, 3 and 4

We have four individual schemes to utilise abstraction licences previously owned by commercial businesses. The licences are now revoked, and we would apply to the Environment Agency for a new abstraction licence. We have costed four abandoned borehole sources across the region, which have a total potential yield of 6.4Ml/d. Each would require a length of pipeline to connect the groundwater source to a water treatment works.

R21: Dam raising Option 1

This scheme involves raising the height of an existing dam wall of a reservoir in the Pennines. We estimate the scheme would increase deployable output by 0.28Ml/d.

R23: Dam raising Option 3

This scheme involves raising the height of the existing dam wall of a reservoir in the Pennines. We estimate the scheme would increase deployable output by 0.05Ml/d.

R24: Dam raising Option 4

This reservoir scheme involves increasing the height of an existing dam of a reservoir in the Pennines. The scheme is expected to increase deployable output by 2Ml/d.

R29: Reservoir de-silting

This scheme aims to increase the capacity of 26 reservoirs through dredging and desilting. The silt would be taken to a landfill site. The scheme is estimated to increase deployable output by 111Ml/d and take 7 years for full implementation.

R34: River Calder abstraction Option 1

This scheme is a new abstraction from the River Calder. It requires construction of a pumping station and water main, and transport of water to an existing water treatment works. We estimate the scheme would provide 10Ml/d and be operational after four years. This scheme would be subject to the Environment Agency granting a licence and specifying constraints at lower flows.

R35: River Aire abstraction Option 1

This scheme is a new abstraction licence on the River Aire. It would involve the construction of a pumping station and water main in order to abstract and then transport water to an existing water treatment works. We estimate the scheme would provide 10Ml/d and be operational after three years. This scheme would be subject to the Environment Agency granting a licence and specifying constraints at lower flows.

R37: River Aire abstraction Option 3

This is a third potential new abstraction site on the River Aire. It involves construction of a pumping station, new water main and bankside storage reservoir. The scheme could also require construction of a new treatment works or the upgrading of an existing treatment works. We estimate it could provide 20Ml/d and be operational after three years. This scheme would be subject to the Environment Agency granting a licence and specifying constraints at lower flows.

R49, R50 and R51: Supply Dales from the Tees

These schemes give three options to supply 15Ml/d of raw or treated water to the Dales from an abstraction on the River Tees. R49 is a raw water import from Northumbrian Water. R50 is virtually the same scheme as R49 but we would apply for our own abstraction licence on the River Tees. R51 is a treated water import from Northumbrian Water.

R54 and R56: Tees to Ouse pipeline

This is an alternative to the above scheme where the water will be abstracted from the River Tees and delivered to our treatment works by a raw water main. R54 is a raw water import from Northumbrian Water, whereas R56 is the same scheme but we will apply for our own abstraction licence on the river Tees. The scheme is designed to be delivered in three phases to allow flexibility in the option.

R58: Transfer from United Utilities Option 2

This scheme would utilise an existing pipeline connection between United Utilities and Yorkshire Water. The transfer would provide 1Ml/d of raw water for use in the Grid SWZ.

R59: Transfer from United Utilities Option 3

This scheme would install 6km of pipeline to connect the Grid SWZ to an existing United Utilities' pipeline. The transfer would supply the Grid SWZ with 1Ml/d of treated water.

R61: Desalination

This scheme involves construction of a water treatment works on the East Yorkshire coast to treat sea water. The scheme involves construction of; pumped beach wells for seawater abstraction, water mains from the wells to the water treatment works, and water mains from the water treatment works to the Grid SWZ supply network. The scheme would employ reverse osmosis as a 'lower-energy' method of desalinisation. The water treatment works would include pre-treatment, post-treatment and energy recovery, and is predicted to increase deployable output by 20Ml/d. The scheme would be implemented after six years dependent on appropriate planning and environmental investigations.

R62: North Yorkshire rural distribution enhancement

This scheme will link a rural area in North Yorkshire, predominantly supplied by a groundwater source, to a water treatment in York. It will require a new clean water pipeline to connect to the WTW and allow transfer of at least 1Ml/d. This will be within current licensing permissions.

R63: North Yorkshire groundwater option 2

This scheme will require a licence application for an additional abstraction of 1Ml/d from an existing groundwater source in North Yorkshire. Current infrastructure will be sufficient to abstract the additional supply however, for resilience an additional borehole will be drilled to provide a standby asset. UV treatment will also be installed.

R72: River Wharfe licence increase

We have an option to increase the maximum volume we are permitted to abstract from the River Wharfe. We have an existing abstraction licence that is limited to an annual average abstraction of 65.05Ml/d. This option is to apply for a variation to the current licence to allow an annual average abstraction of 75.05Ml/d. No additional infrastructure will be required. This provides an addition 10Ml/d; however, it will only be required to meet demand in years when we experience significant demand increases due to low rainfall and excessive freeze-thaw (pipes bursting due to cold weather conditions).

E1: Transfer to United Utilities

This scheme is a Yorkshire Water export to United Utilities. It requires a 5Ml/d release from a Yorkshire Water reservoir into the Huddersfield Canal for United Utilities to abstract downstream. United Utilities does not require this export as part of its WRMP 2019 solution.

E2: Transfer to Severn Trent Water

This scheme is a Yorkshire Water export to Severn Trent Water. The scheme is designed to provide 20Ml/d treated water on average and 25Ml/d peak, via a new pipeline from South Yorkshire to Severn Trent Water's supply area. We would be required to construct a new storage reservoir adjacent to an existing storage reservoir used to supply our customers. Severn Trent Water does not require this export as part of its WRMP 2019 solution.

17.3 Appendix B: Yorkshire Water optimisation model

Our optimisation model determines the least cost solution from the monetary, environmental and social costs and benefits of the feasible options, using the methodology recommended in the *Economics of Balancing Supply and Demand* (Environment Agency and UKWIR, 2002). The assumptions, constraints and data inputs used in the model are listed below.

The costs and benefits included in the model for each feasible option are:

- Capital expenditure – initial build costs and replacement. Divided into civil, land, mechanical and engineering and ICA (instrumentation, control and automation)
- Operating expenditure - fixed and variable
- Environmental and social capex build and replacement
- Environmental and social opex - fixed and variable
- Carbon capex build and replacement
- Carbon opex- fixed and variable.

In addition to the above we input the following for each individual schemes:

- The build ramp up with cost spread out where required, i.e. capex expenditure is spread over the number of years it takes to deliver a scheme
- The yield provided by scheme (either an increase in resource or reduction in demand)
- The earliest date the scheme can provide yield (either partial or 100% depending on individual schemes). This allows for the planning and build time that is required
- The yield build up. Some schemes provide 100% of yield once the scheme delivery is complete other schemes such as metering will produce a gradual build-up of yield as meters are installed over a number of years
- Supply demand over 25 years or 40 years – this gives the surplus/deficit for individual years.

The model determines the least cost solution by calculating the whole life costs of options over 100 years (the lifetime of the longest lasting asset), starting from the year the scheme build starts.

The least cost solution provided by the model is for a 25 year or a 40 year time period starting 2015/16 (first year of AMP6).

In accordance with Environment Agency 2016 guidelines we have used a discount rate of 3.6% for financing costs and for all other costs used the Treasury Discount rate as set out in the HM Treasury “Green Book”.

The price base for costs is 2016/17 – where applicable costs have been inflated to this base.

If an option is dependent on another option, this has been accounted for in the model so that only one can be selected if they are exclusive (e.g. only one of the two Tees to Ouse transfer options can be implemented). Or if an option is linked to another option and one is a prerequisite of the other (e.g. D2 three phases of pressure management) this is accounted for in the model.

The environmental and social costs have been calculated using the *Benefits Assessment Guidance* (EA, 2012) and are described in the *Draft WRMP 2013 Environmental Economics technical submission* (Yorkshire Water, 2013). The carbon cost calculations are also described in this report.

17.4 Appendix C: Customer engagement for PR19 and WRMP19 planning

17.4.1 Overview

As a fundamental part of PR19 and WRMP planning, we have undertaken a significant programme of customer engagement. This has helped us understand more about what is important to our customers now and in the future.

We have talked to our customers about how water plays a part in their lives and the dependencies that we all have on water. These conversations have helped us to develop our long-term strategy, which we published in January 2018.

As part of our last strategy review in 2013, customers told us their priorities for the next 25 years. This led to key long- term outcomes for Yorkshire Water and a series of performance commitments against which we measure ourselves for the period 2015-2020.

In preparation for PR19 and the development of our draft WRMP19, we set about gaining an in-depth understanding of our customers, to ensure that we meet their expectations in both the foreseeable future and over the long-term.

17.4.2 Valuing Water

Prior to customer engagement we consulted the data we already hold as a company. This involved a review of incident data, customer call volumes, customer complaints and social media interactions, to understand the areas causing greatest customer dissatisfaction. The findings informed our first primary research study, called Valuing Water. The Valuing Water project used a multi-method approach to explore the value customers place on our services. It sought to understand customer expectations and aspirations for Yorkshire Water and the services we deliver, in the context of the macro-level challenges we face on population growth and climate change.

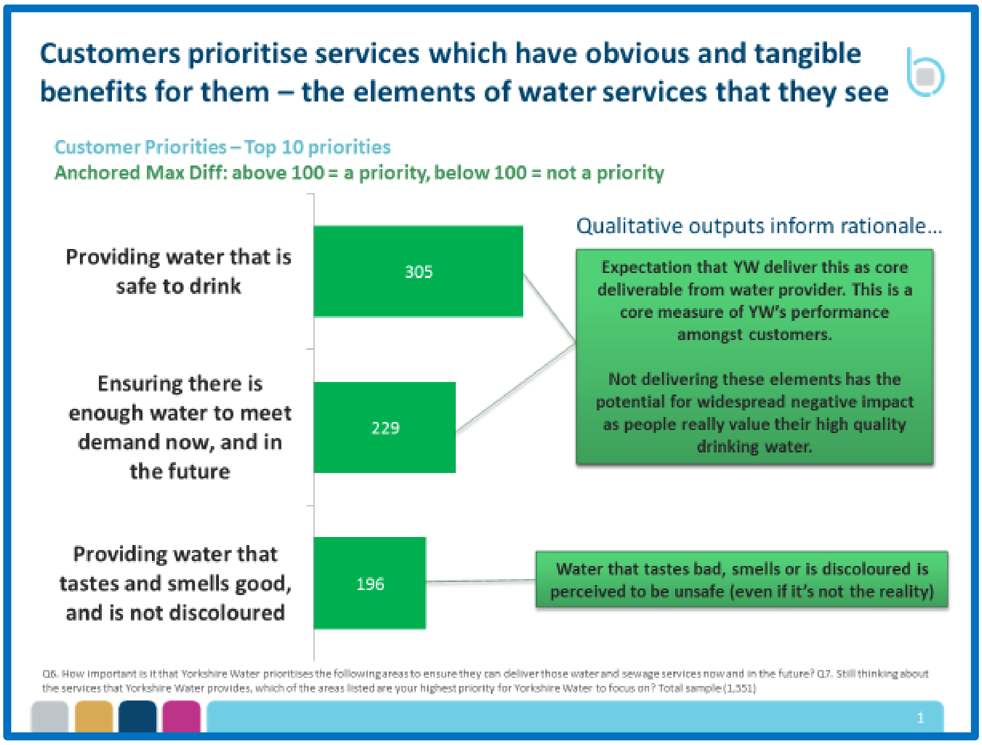
From this early study, our customers primary long-term priorities included:

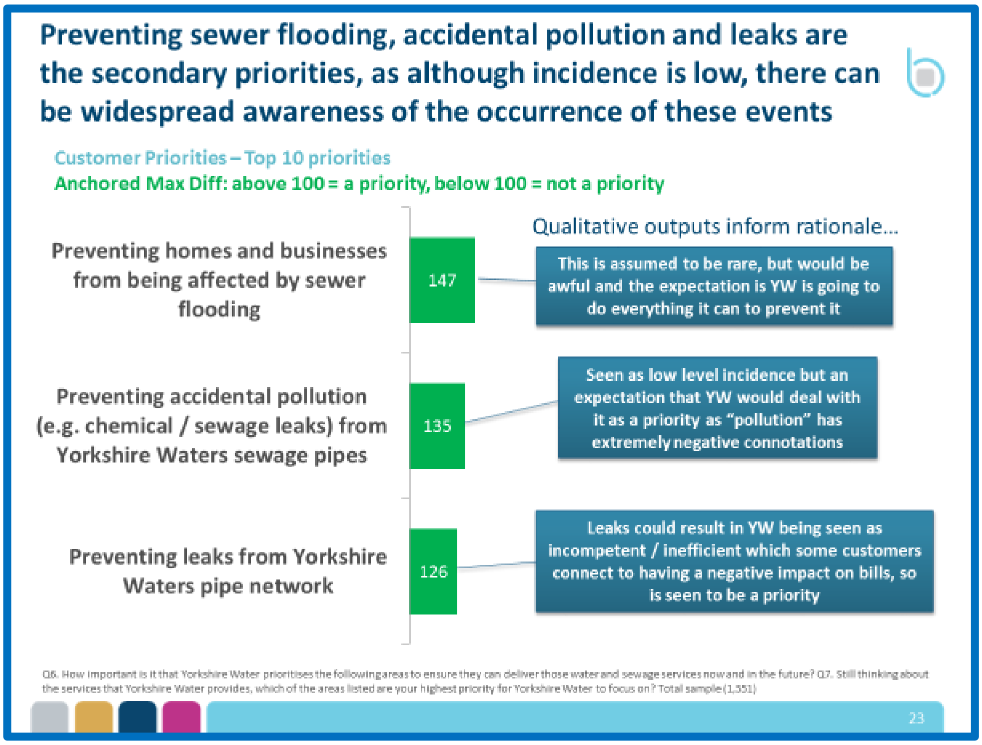
- Reducing water wastage and leaks;

- Ensuring appropriate plans are in place to service a growing population and cope with climate change;
- Focus on flood management and flood defences; and,
- Working with partners and ensuring measures are in place to protect water quality

Figure 17.1 shows our customers' top priorities in the shorter-term, out of the 20 service measures tested.

Figure 17.1 Top customer priorities





From a water resource planning perspective, the study showed that customers' priorities were provision of a continuous and safe supply of drinking water and leakage prevention.

This, as well as a specific online community study on leakage, outlined below, guided our early position on leakage as it was clearly a customer priority.

17.4.3 'Your Water' leakage engagement

We have engaged an online community, 'Your Water', to allow us to undertake more dynamic research studies and answer specific questions to gain customers insight on a range of topics. The community has over 1000 customers and is a nationally representative sample from across the region. In May 2017 we explored leakage with the online community to understand perceptions of leakage and willingness to pay more to reduce leakage from the current level. The findings showed that, while most were happy with our performance and approach to leakage (55%), a significant proportion (45%) were either dissatisfied or indifferent about our performance mainly due to the volume of water lost. 64% of these customers felt there was more we could do to reduce leaks and 68% supported an increase in their bills to improve this position.

Customers were presented with several scenarios of potential leakage reduction by 2025. Two in three customers were willing to pay more to reduce leakage volume, with 20% of customers supporting a bill increase to reduce leakage by 50Ml/d - a reduction of 16% from the current leakage position. The results of the survey are shown in Table 17.2 below.

Table 17.2 Results of customer views on leakage levels

Scenario for 2025	Customer Support
Not willing to pay any more to reduce leakage	32%
Reduce leakage at current rate saving 10 Ml/d	27%
Ambitious reduction of leakage saving 25 Ml/d	21%
Maximum possible reduction of leakage saving 50 Ml/d using traditional techniques technologies	20%

17.4.4 Comparability of Data & Long-Term Aspirations

The Valuing Water and ‘Your Water’ studies provided evidence for an improvement in our leakage performance. This was supported by a Comparability of Data and Future Aspirations study carried out in Spring 2017, which showed that a step change in leakage ambition was required.

This study sought to understand how customers view the performance of our current service levels across a number of service measures when compared to the performance of other utilities companies, and in the context of the average bill value. The overall objective was to understand customer views on current performance and where they would like to see our performance in the future.

An extensive qualitative approach was used to explore in depth the views of key customer groups on our performance. This qualitative research was adapted to be repeated and quantified on our online community, ‘Your Water’.

The findings revealed that awareness or knowledge of our performance was limited amongst our customers. Once we revealed our current performance (based on 2015/16 data) and where we were hitting or missing the targets set for the period in 2015, 90% of customers were satisfied with current performance. A small number suggested that targets might not be challenging enough given our positive performance. Overall, there was little concern around underperformance on the three measures we were failing to achieve at the time (drinking water quality, energy generation and sewer collapses).

However, when compared to the wider industry, our underperformance was seen as much more significant. Even measures that were on target were questioned and customers supported more stretching performance commitments across the board.

Under our 'We make sure you always have enough water' outcome, customers were mainly concerned about leakage and mains bursts. A number had already indicated they thought the targets were too high and the comparative data revealed that the company is below average on the volume lost through leakage and 'industry lagging' when it came to the number of burst mains. This information suggested to customers that other companies are investing more in their networks and/or doing more maintenance, and that we needed to improve.

For most, seeing that on average, Yorkshire Water customers were paying £32 a year less at the time compared to customers of other water companies, made them feel slightly more positive about our relative performance. At the same time, there was recognition that lower bills might mean reduced investment, resulting in below industry average performance on several measures.

Customers believed that Yorkshire Water should be at least industry average across all measures and expected speedy improvement on 'industry-lagging' performance commitments and a majority of customers were willing to accept an increase in bills to achieve this.

Your Water

62% Expect performance to be above average

74% Would pay more to see YW above or equal to the industry average

Regarding future performance, there were only two performance commitments where a large but gradual improvement was expected:

- Yorkshire Water minimises the amount of water that is lost from the network; and,
- Yorkshire Water generates energy using renewable technology.

The volume of water being lost from the network was a cause for concern from the beginning of the discussions/interviews, so it was not unexpected that customers wanted to see significant improvements in this measure.

This study was conclusive about our customers' expectations on current and future leakage performance. This informed our leakage ambition for PR19 and beyond.

17.4.5 Outcomes & Performance Commitments

All of the research undertaken shaped the development of our Business Plan submission and the content of our WRMP19. A key part of this was the development of our Outcomes and Performance Commitments for 2020-2025.

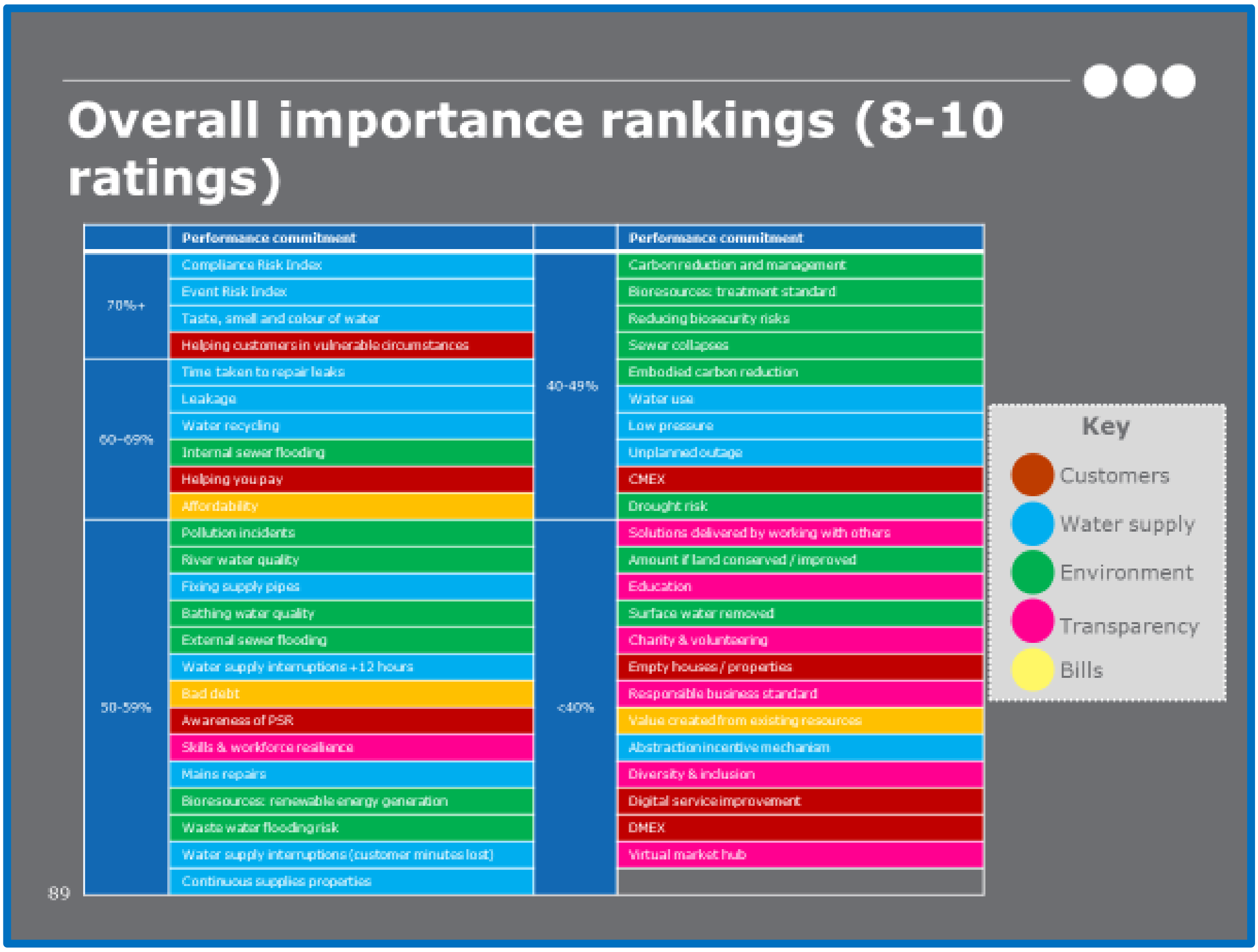
All customer insight gathered through the research projects were combined with company aspirations to develop a set of five new 'big goals' and performance commitments. These goals and performance commitments were tested with customers through a significant qualitative research project undertaken with customers right across our region, including vulnerable and ethnic minority customers. The aim was to achieve a package of outcomes, performance commitments and incentives that customers understand and are happy to support.

The findings showed that overall there was a high level of support for the big goals and performance commitments, with 'Water supply' and 'Environment' being the strongest goals in terms of levels of support; around 90% of customers surveyed supported the water supply big goal.

Tying into support for the big goals, performance commitments related to Water Supply were amongst the performance commitments considered to be the most important overall. Out of the top 10 of the 49 performance commitments tested, 6

commitments are included in the Water Supply category (leakage, compliance risk index, taste, smell and colour, time taken to repair leaks, event risk index). Figure 17.2 shows the order of importance for all 49 performance commitments tested.

Figure 17.2 Overall importance of performance commitments tested with customers (% of customers who scored each measure as 8-10 importance)



Overall importance rankings (8-10 ratings)

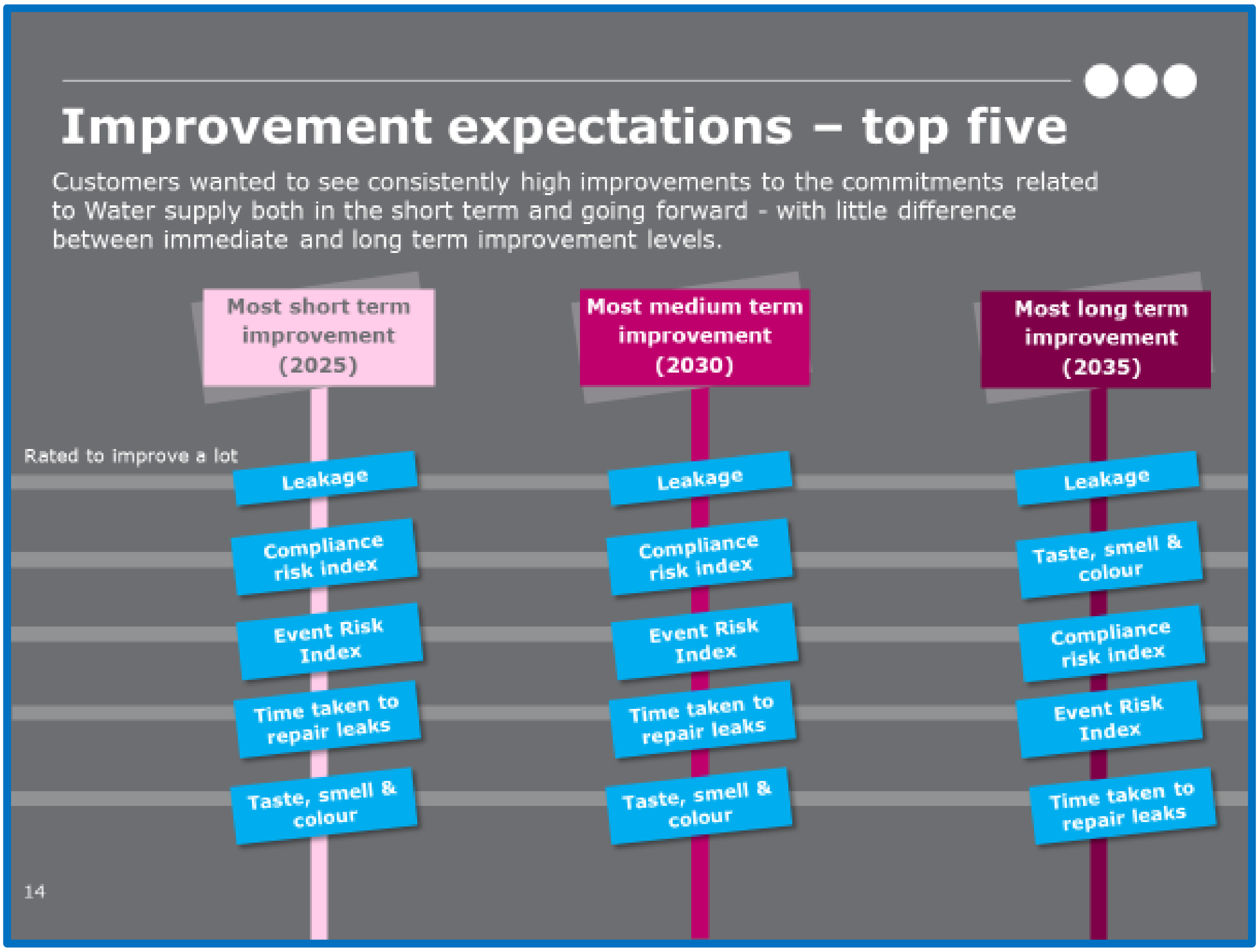
	Performance commitment		Performance commitment
70%+	Compliance Risk Index	40-49%	Carbon reduction and management
	Event Risk Index		Bioresources: treatment standard
	Taste, smell and colour of water		Reducing biosecurity risks
	Helping customers in vulnerable circumstances		Sewer collapses
60-69%	Time taken to repair leaks		Embodied carbon reduction
	Leakage		Water use
	Water recycling		Low pressure
	Internal sewer flooding		Unplanned outage
	Helping you pay		CMEX
	Affordability		Drought risk
50-59%	Pollution incidents	<40%	Solutions delivered by working with others
	River water quality		Amount if land conserved / improved
	Fixing supply pipes		Education
	Bathing water quality		Surface water removed
	External sewer flooding		Charity & volunteering
	Water supply interruptions +12 hours		Empty houses / properties
	Bad debt		Responsible business standard
	Awareness of PSR		Value created from existing resources
	Skills & workforce resilience		Abstraction incentive mechanism
	Mains repairs		Diversity & inclusion
	Bioresources: renewable energy generation		Digital service improvement
	Waste water flooding risk		DMEX
	Water supply interruptions (customer minutes lost)		Virtual market hub
	Continuous supplies properties		

Aligned with the Comparability of Data Study, we provided customers with comparative performance data for the year 2020 (where available) for each of the performance commitments. This was used as a starting point for customers to assess how far they would like the business to progress in the 5-year period and beyond. From this exercise, we learned once again that, customers were not content with our relatively poor performance compared to the wider water industry in areas such as leakage and water quality.

Most customers had expected Yorkshire Water to be in the top half across the board and wanted to see improvements. They wanted to see consistently large

improvements in the performance commitments related to Water supply (drinking water quality, taste and odour, leakage, supply interruptions etc.) both in the short-term and into the future. Leakage was one of the performance commitments with some of the highest levels of suggested improvements in the short, medium and long term, as shown in 17.3.

Figure 17.3 Performance commitments with greatest expected improvements over the short, medium and long-term



17.4.6 Acceptability testing of the PR19 Business Plan

Between June and August 2018, we carried out our final PR19 customer insight research – acceptability testing of our Business Plan for PR19.

This was an extensive programme of qualitative and quantitative research with a wide range of our customers: household, non-household, vulnerable and future customers.

The study presented the business plan under the headings of the big goals, with a summarised view of what we will deliver under each. Customers had an option to explore the performance commitments relating to each big goal in more detail, including proposed targets and projected progression throughout the 5-year period for each commitment. An example of the Water Supply summary is shown in Figure 17.4.

Figure 17.4 Water Supply big goal, a summary of what will be delivered between 2020-2025

WE WILL ALWAYS PROVIDE YOU WITH ENOUGH SAFE WATER, WE WILL NOT WASTE WATER AND ALWAYS PROTECT THE ENVIRONMENT

What this means for our customers over the next 5 years

- We will **reduce leaks by 40%** by 2025
- We will commit to **repairing customers leaking supply pipes for free**
- We will **reduce water interruptions** for customers, becoming a leader in the industry
- We will **improve our water appearance** so fewer customers need to contact us about the taste, smell or colour of it
- We will reduce our impact on the environment by **recycling the water we use** and using rain water where drinking water isn't needed.
- We will **save 5% of our drinking water** by working with large businesses in Yorkshire to change the way they use water in their own processes for example, using recycled water rather than drinking water
- We will continue to work with our customers to **reduce water use**

The high-level final results are conclusive, 86% of customers supported our business plan proposals and the outcomes that we will deliver between in AMP7. This includes our ambitious target for leakage (amongst others) and the price increase proposed to help us achieve all we set out in our plans.

Customer support for all five big goals was high (92% to 96%), however the Water Supply big goal had the highest support from our customers, with 96% of both household and non-household customers either supportive or very supportive of this goal.

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