love every drop
anglianwater

# PR24

## Asset System Resilience Appraisal

## Anglian Water

## October 2023

# Contents

## Foreword

We supply drinking water and recycle used water for around seven million people in the East of England and Hartlepool. To carry out this vital public service we own, operate and maintain a vast array of physical assets from reservoirs, pipelines and tanks to pumps, treatment plants and control systems. The replacement value of these assets amounts to over £67bn in today's prices.

Our assets are a vital part of our ability to deliver our purpose of bringing environmental and social prosperity to the East of England. Every day our teams use them to provide safe clean drinking water, protect the environment and deliver excellent service. Central to this is ensuring we take the time to understand asset health and potential consequences of failure, in order to prioritise activity and target investment in the right places.

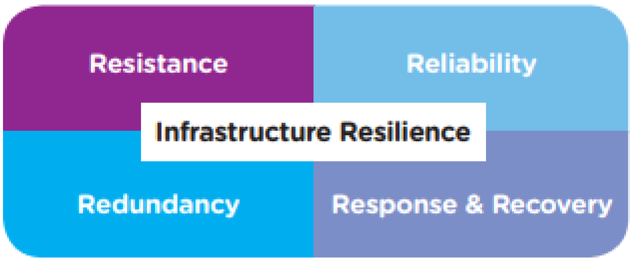
This Asset Systems Resilience Appraisal ("ASRAP") is a central part of how we will deliver against the four long term ambitions set out in our Strategic Direction Statement:


This ASRAP outlines our long-term strategic plan for asset health related activity. It sits alongside our other strategic planning frameworks for other aspects of our business such as the Long Term Delivery Strategy (LTDS), Water Resource Management Plan (WRMP), Drainage and Wastewater Management Plan (DWMP) and Water Industry National Environment Programme (WINEP).

Long term thinking is central to all of these documents. The ASRAP is no different. As a result, we therefore plan to update this and make it an iterative document, learning from experience and improved tools and techniques available at the time and reflecting how our operating conditions and the assets we are stewards, change now and in the future.

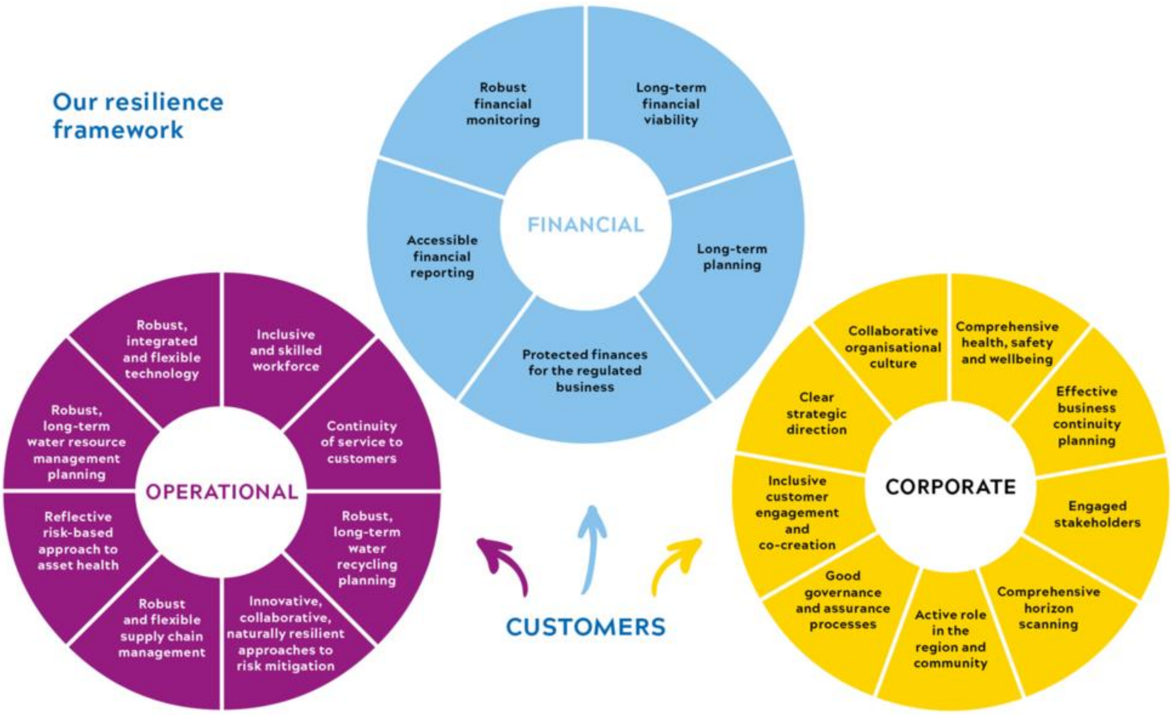
The purpose of this document is to provide our Board and stakeholders with insight into the long-term sustainability of service performance. We do this by assessing the assets we are responsible for against a suite of risk both in the short and longer term.

We recognise the importance of understanding asset health in our organisation as it underpins our ability to provide service. The asset system resilience appraisal we have commissioned is our way of comprehensively assessing the vulnerability of our assets to different failure modes, and we will use it in future to increase our Resistance, Reliability, Redundancy and prepare for Response and Recovery, as set out in the Infrastructure Resilience Components (Cabinet Office, 2011):




At PR19, in conjunction with the development of our revised SDS and PR19 Business Plan, we developed with Arup we developed our Framework for Resilience: PR19 and Beyond[1]. This set out how our biggest challenges are climate change, growth and the need to protect the environment. This highlighted that as well as being able to cope with these particular long-term challenges, we need to be resilient to shocks and stresses, now and in the future, that can impact on our ability to maintain services for our customers and protect the environment. This framework focussed on the drivers underpinning financial, operational and corporate resilience:

*Figure 1: Anglian Water Resilience Framework*




This framework is designed to enable Anglian Water to think about short-term management of risks, alongside longer-term trends and lower likelihood risks. The framework is designed to help Anglian Water to become a truly resilient water company for the benefit of their customers and the environment. This framework defined operational resilience as:

[1] a-framework-for-resilience-pr19-and-beyond.pdf (anglianwater.co.uk)

***"the ability of our organisation's infrastructure, and the skills to run that infrastructure, to avoid, cope with and recover from, disruption in its performance".***

Embedded in the consideration of operational resilience, is a the need to reflect a risk-based approach to asset health which stated:

**Reflective risk-based approach to asset health**

*"There should be a comprehensive assessment of asset risk, including long-term low-likelihood risks, having detailed and accurate information on the state of assets, the way they are configured and the way they are operated.*

*The focus should be on criticality; protecting customers and the natural environment from exposure to known risks, and reducing vulnerability to future uncertainties.*

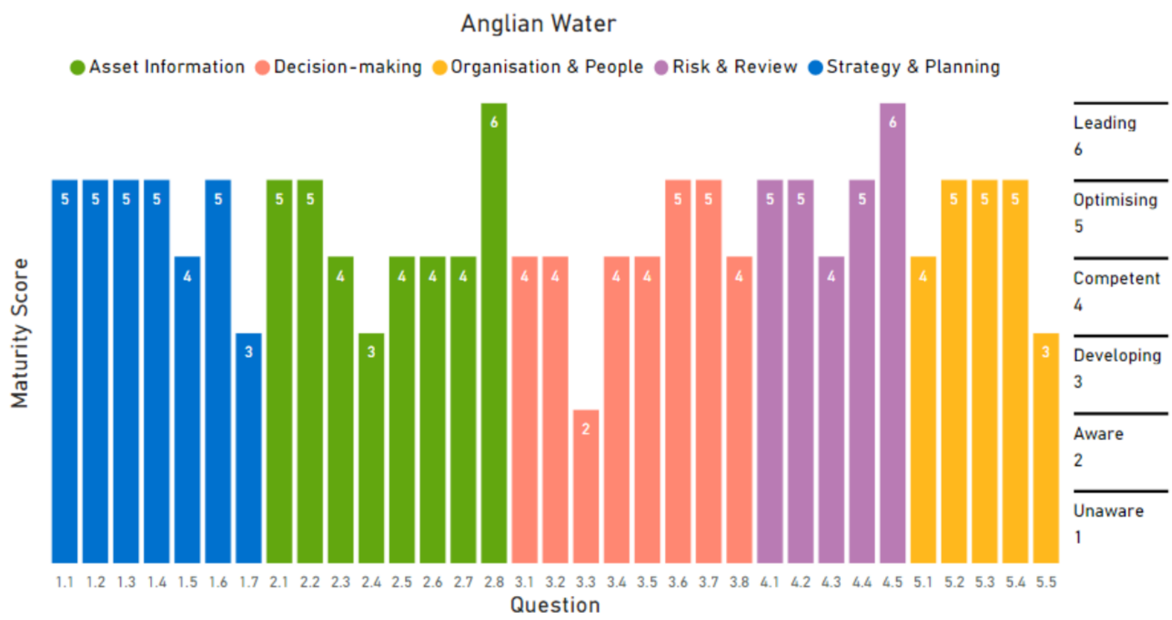
*There should be a region wide asset strategy which is adaptive, regularly reviewed and has considered the changing requirements into the long-term (25 years).*

*They should follow recognised best practice for asset management, such as ISO 55000".*

**Working collaboratively to develop Asset Management and Asset Health approaches**

Subsequent to PR19, we have worked collaboratively with Ofwat and other water companies to co-create and complete the Asset Management Maturity Assessment (AMMA)[2]. This was a significant undertaking for the sector, seeking to understand the respective maturity and leadership of Asset Management approaches across a suite of relevant factors.

*Figure 2: Anglian Water Asset Management maturity assessment results*




This AMMA assessment demonstrates the maturity of our approaches to Asset Management across the Board, highlight our strengths and leadership in this area.

In the company specific feedback Ofwat evaluated our overall maturity as the highest in the industry. Since receiving the feedback we have both shared best practice with other water

[2] Asset management maturity assessment (AMMA) - Ofwat

companies and continued to improve and refine our own framework. In relation to the questions on strategy and planning, Ofwat stated, *"To improve its maturity in this area, Anglian Water could consider how to further develop its use of asset health trends and forward-looking measures to inform and refine its asset management plan".*

**Developing the Asset Systems Resilience Action Plan ("ASRAP")**

We share Ofwat and wider stakeholders' view of the critical nature for companies to develop and apply the very best practices to understanding the resilience of their operations to a wide range of future shocks and stresses.

The development of our ASRAP builds on both the need to develop risk-based approaches to asset health set out in our PR19 resilience framework and this company specific feedback. It is also consistent with Ofwat's recent Operational Resilience consultation which restates the link between asset health and service performance[3].

The development of the ASRAP responds directly to the Strategic Policy Statement[4] setting the Government's strategic priorities for Ofwat, which states *"Good asset management is a key factor in delivering long-term resilience. We expect companies to demonstrate a clear understanding of the health of their assets over the long-term and how this impacts the resilience of their services. Effective management of assets will support future resilience of service and provide benefits to the environment and society through, for example, reduced environmental harm and fewer flooding and pollution incidents. We expect Ofwat to: Promote good asset management and challenge companies to better understand the health of their assets and adopt a strategic and long-term approach. This approach should provide for resilient services taking account of growing pressures, including climate change and population growth, and the needs of a healthy environment, and provide value to customers and wider society in the longer-term."* In addition this document satisfies condition 'L' of our licence, the requirement to produce 'Underground Asset Management Plans'[5].

**Conclusion**

In development of the ASRAP, we have completed the most holistic review of the resilience of our entire asset base we have ever attempted. This review has been timed to inform, the Price Review 2024 (PR24).

The outputs have also been used to inform maintenance planning, emergency response and business cases for future investment and have been provided to the National Infrastructure Commission (NIC) to inform the new publication of the National Infrastructure Assessment.

We have followed the principles of this framework in our asset system resilience appraisal, and supplemented the engineering assessments with financial measures of sustainability, and believe the evidence we have assembled is consistent with Ofwat's expectations to demonstrate the need for increased maintenance allowances in the period beyond 2030, and for increased spending to tackle specific resilience threats in the period 2025-2030.

**The purpose of this document is to set out the results of our comprehensive bottom-up forward looking review.**

---

[3] Publication of Targeted Review of Asset Health - Ofwat

[4] February 2022: The government's strategic priorities for Ofwat - GOV.UK (www.gov.uk)

[5] Anglian Water Licence (ofwat.gov.uk)

## Executive Summary

**We understand our asset base and have robust systems in place to understand the impact of risks on these assets and their ability to provide service to our customers.**

We were the first water company to achieve ISO55001 accreditation, and for many years lead the Asset Management workstream at UKWIR, as well as being active participants in the International Water Association LESAM (Leading Edge Strategic Asset Management). This demonstrates our track record of experience which we have used to lead the industry in how to assess asset health risks.

In 2021, Ofwat's assessment Management Maturity Assessment (AMMA) demonstrated that we are leading in the UK Water Sector. We have established forward-looking engineering models which have been progressively improved since PR09, and can now predict performance further into the future, helping inform projections of company performance in our new Long Term Delivery Strategy (LTDS).

We have also developed tactical models such as WISPA (Water Infrastructure Serviceability Performance Assessment), which use detailed analysis of real world failure data to provide month by month predictions of burst rates by pipe, linked to soil condition and climatic changes, demonstrating our deep knowledge of the asset health of our water mains.

Our customers tell us that they trust us to understand these issues and expect us to be good stewards for future generations.

**We understand the long term impact of a changing climate on our assets**

As part of our delivery process we routinely assess the risk of climate change on assets so that future climate impacts can be avoided in the design phase. In practice most of our asset base is already witnessing climate change impacts now. As part of our Climate Adaptation Strategy 2020, we sought to better understand the risk to our historic asset base and have combined our strategic and tactical models to improve our forecasts and take account of our changing climate. Working with expert academics we are now able to isolate vulnerable assets and predict the impact of climate change on likelihood of failure into the long term. This includes pipes affected by increasing ground movement and mechanical and electrical assets that require new cooling systems to avoid overheating.

We use industry leading tools such as Copperleaf Predictive analytics (PA) to help develop our understanding further, by predicting the effect on long term performance of different investment strategies.

**Our systems and approaches are subject to external assurance and scrutiny**

We undertake an annual external review by the British Standards Institute (BSi) to retain our ISO55001 accreditation. Our Business Plan has also included external assurance by Jacobs on the use of Predictive Analytics to model climate change impacts. In addition, we have been externally recognised as winners of the 2022 Asset Management Initiative of the year at the Water Industry Awards. We also sought the views of Dr Harry Bush in light of his PR19 work (with John Earwaker) on forward looking capital maintenance assessments[6].

**These approaches inform our capital maintenance activity and how this has evolved over time**

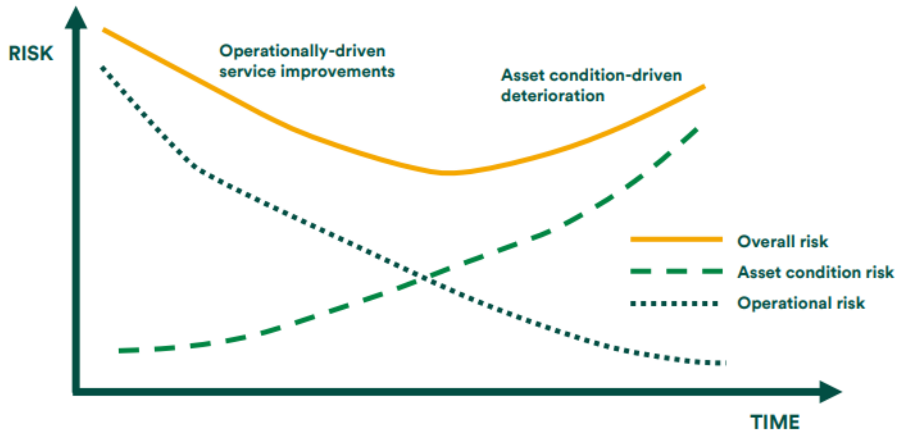
[6] 4a-providing-appropriate-regulatory-funding-for-capital-mainteance-activity.pdf (anglianwater.co.uk)

We have always spent our base allowances in the past. Over that period base expenditure delivered historical service levels alongside historical demands on our assets as witnessed through the performance metrics of the time.

We don't just focus on "traditional" proactive and reactive maintenance of assets. Rather, we have been able to smooth some of this impact over time using operational interventions and state-of-the-art risk evaluation and decision making. We are transitioning to more digital ways of managing the performance of our assets – for instance sewer monitors that provide early warning of blockages that could cause pollutions, catching them before they happen, or using machine learning to monitor pump performance and call for proactive maintenance before failure.

However, whilst these interventions improve service, they don't improve underlying asset health and don't last forever as a strategy. Once all of the network is smart and optimised there are diminishing returns. We see this in practice as we have installed advanced pressure management or variable speed pumps to reduce pressure transients in most of our treated water network. This effect is echoed by others in the sector, in particular United Utility's paper on asset health submitted to the future ideas lab[7] which contained this illustration:

Figure 3: Operational improvements and innovation can mask underlying asset condition deterioration – for a time




**Our approach for PR24**

**We have set out to improve our approach to assessing the long-term performance of our assets**

In response to Ofwat's ask to define 'what base buys' in the long term, there is an expectation of companies to take account of the approach set out in LTDS guidance[8]. This proposed approach to determining future performance delivered from base is backward looking only in nature, using historic observed performance trends.

We believe to assess the role of existing base expenditure on service requires a detailed analysis, informed by an assessment of forward-looking asset health. These findings can then be considered as well as using top down backward looking econometric approaches. The Final Methodology notes that bottom-up approaches would be taken into account when setting Performance Commitment Levels for 2030. Fundamentally, the stability of future performance is a function of whether

[7] UU's paper on asset health in the future ideas lab
[8] PR24-and-beyond-Final-guidance-on-long-term-delivery-strategies_Pr24.pdf (ofwat.gov.uk)

maintenance levels are sustainable. The future is different to the past, and will lead to different demands for maintenance.

To complete the forward-looking assessment we have grouped our vast £68bn asset base into nine asset classes that share common characteristics so they can be modelled together using statistically significant drivers of likelihood of failure.

This does not cover our whole asset base; we have significant capital maintenance expenditure requirements on other unmodelled assets; water meters and meter chambers, long sea outfalls, overflow screens, pipe bridge structures, back-office IT systems, fleet vehicles, emergency response equipment, recreation assets, and health and safety assets like ladders, walkways, hatches, access roads, fencing, security systems. It also doesn't cover investment in new assets deemed to be base to comply with existing permits.

**Developing the unmitigated risk position**

In our unmitigated risk assessment we generate a modelled likelihood of failure using deterioration curves, combined with consequence models that predict the likely impacts of asset failure.

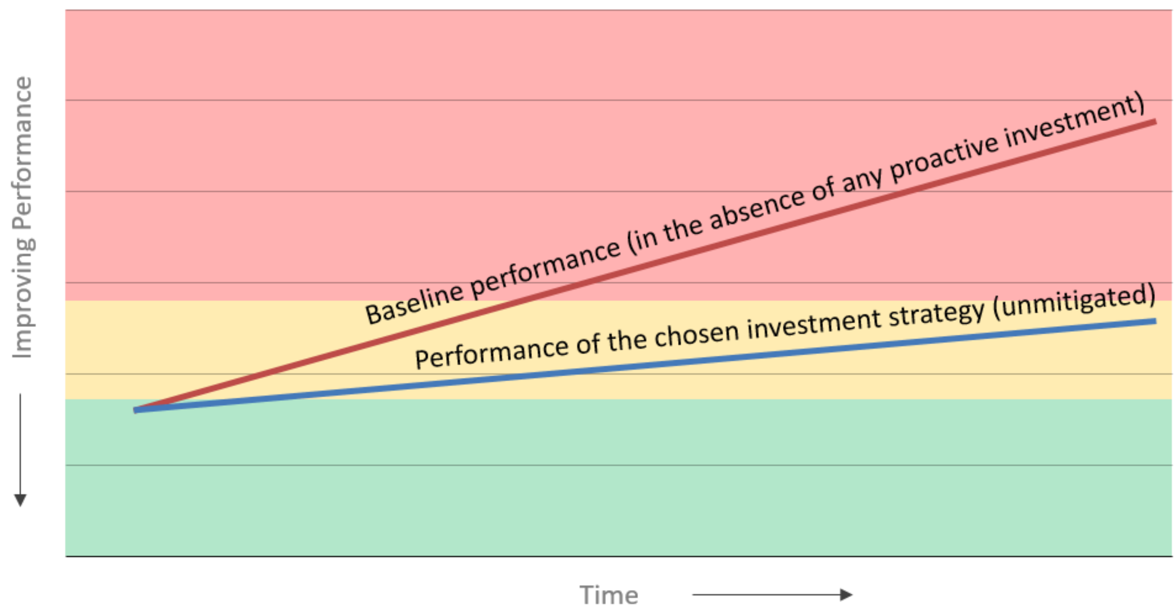
We do this for each asset using hydraulic and process models, GIS analysis and simulations of failure of equipment on our sites.

**This assessment tells us that not all assets have the same unmitigated risk position now or in the future**

Using this unmitigated risk assessment we have derived a Red/Amber/Green for each of the asset classes. The unmitigated RAG is based on the long term trend in residual performance. If residual performance remains flat over time then it's assessed as green since performance at that base level of funding is expected to be stable.

If the residual is increasing over time then it's assessed as amber or red since the base level of funding is not expected to be enough to hold performance stable, instead deteriorating over time. The risk of asset failure is summarised in the following format throughout the document:

*Figure 4: Presentation of results*



### We have a comprehensive approach to understanding the mitigations we can make to our assets

For each of the nine assessed asset classes we have set out clear explanations of the major mitigations that we have considered (operational practices, smarter interventions, or changes into expenditure focussed on these particular asset classes).

We use the impact of these potential "mitigations" by asset class to derive the mitigated positions presenting in the ASRAP.

For example, on water mains we have assessed the impact of mix of operational interventions such as installation of pressure management schemes and optimisation of existing ones in the short term to achieve burst reduction. In other areas, such as storage point maintenance, we have assessed the impact of increased activity and expenditure as a mitigation.

We have conducted this analysis over 3 time periods: 5-year, 10-year and a longer term 25-year horizon to align with our Strategic Direction Statement and Long Term Delivery Strategy.

- Green denotes our assessment of stable performance;
- Amber denotes worsening performance; and
- Red denotes severe deterioration in performance.

We have summarised our findings in the table below. Further detail is provided in the following sections of the ASRAP.

Our analysis shows that after mitigations from operational practices, reallocation of resources and the adoption of smart approaches to network and asset management, asset performance can be held stable and deliver some performance improvement in AMP8 at current capital maintenance expenditure levels, with the addition of enhancement allowances to tackle specific threats relating to climate risk, physical and cyber risk, flooding and single points of failure.

However, from AMP9 we expect to need to increase spending on asset replacement and renewal, as we illustrate for the longer term below:

*Table 1: Modelled prediction of asset performance - summary over 25 years.*

| Asset class | | Unmitigated | | | Mitigated | | | Comments |
|---|---|---|---|---|---|---|---|---|
| | | 5 year | 10 year | 25 year | 5 year | 10 year | 25 year | |
| **Pipelines** | 1.1 Treated water mains | ↘ | ↓ | ↓ | ↔ | ↘ | ↓ | Mitigation via smart networks, and climate resilience programme |
| | 1.2 Gravity sewers | ↘ | ↓ | ↓ | ↔ | ↘ | ↓ | Short term mitigation via smart networks, and advanced pipe selection |
| | 1.3 Rising mains | ↔ | ↔ | ↔ | ↔ | ↔ | ↔ | |
| **Treatment** | 1.4 Water treatment works | ↔ | ↔ | ↘ | ↔ | ↔ | ↘ | Short term funding required for cooling systems |
| | 1.5 Water recycling centres | ↔ | ↔ | ↘ | ↔ | ↔ | ↘ | Amber after 25 years due to uncertainty in modelling over extended time frame. |
| | 1.6 Bioresources | ↔ | ↔ | ↘ | ↔ | ↔ | ↘ | |
| **Pumping** | 1.7 Boosters | ↔ | ↔ | ↔ | ↔ | ↔ | ↔ | |
| | 1.8 Sewage pumping stations | ↔ | ↔ | ↔ | ↔ | ↔ | ↔ | |
| **Storage** | 1.9 Storage points | ↘ | ↓ | ↓ | ↔ | ↘ | ↓ | Short term mitigation via reallocation of funding in base |

These findings suggest that asset classes that are primarily dependent on short life mechanical and electrical assets to achieve performance have been prioritised in maintenance budgets, with longer lived assets such as buried pipelines and concrete or steel tanks having expenditure levels that appear unsustainable in the long term.

We've also thought about resilience in broader terms not just asset failure, and have outlined our strategies that address other asset shocks and stresses that could impact performance, for example risks of power outage to the site, flooding of the site, or security breaches.

### This has informed our mitigated view of balanced interventions

This view of predicted performance in the analysis we have conducted forms the basis of our plan for AMP8. We believe we have followed a thorough process, and competently and comprehensively demonstrated our bottom-up view at an asset class level of detail. We are not looking at this in an alarmist way, with only today in mind but have placed immediate requirements in the context of a mature long-term strategic approach in line with the recommendations of the AMMA process, that will benefit our customers and the environment in the long term. We will continue to update this view at future price reviews and make the case for increased base expenditure where the evidence shows this is required to sustain performance.

### We plan to work constructively with Ofwat and other companies to prepare for PR29

In 2022 we responded to Ofwat's consultation on Assessing Base Costs, providing suggested alternate approaches to determining future maintenance allowances. Advances in widespread asset monitoring mean that we now have more data available than ever before. Where we have gaps in our understanding we will work to close these and iterate our appraisal, working closely with Ofwat and other stakeholders to prepare for future price reviews, adopting a forward-looking approach to determining appropriate levels of base activity to ensure performance is sustainable in the long term.

## Introduction

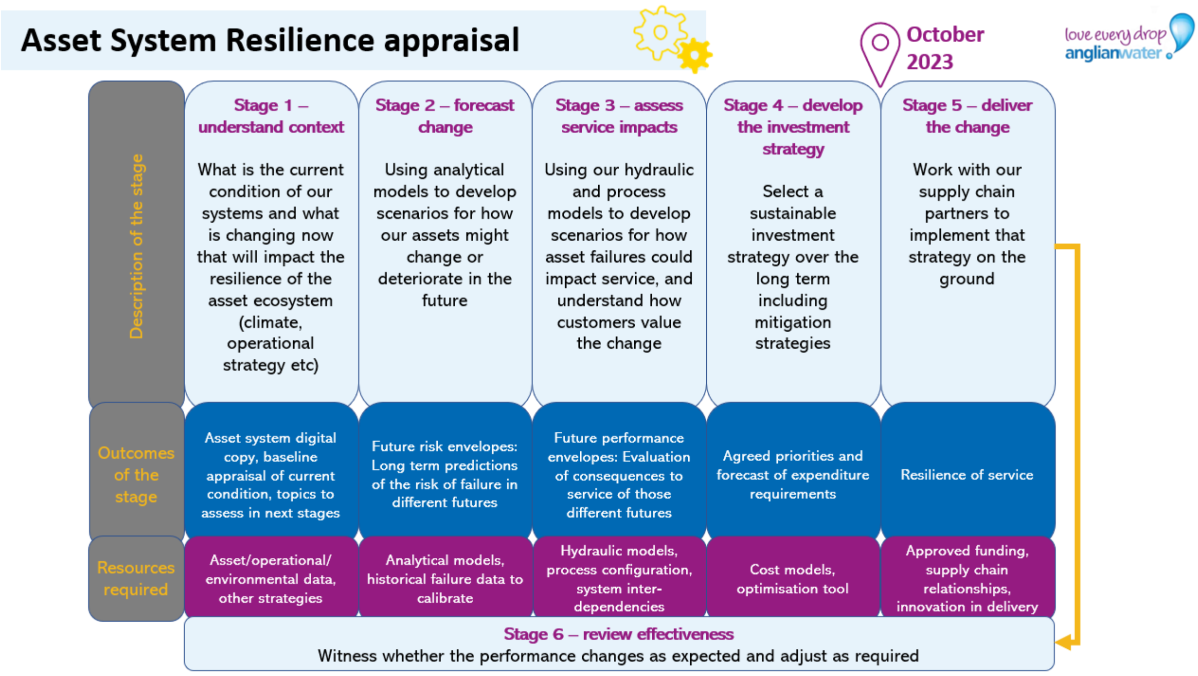
We have been providing water and sewerage services to the East of England since 1974 and Hartlepool since 1997, and some of our assets have been in service for up to 150 years. We are a business that operates over the long term.

Our Asset Management Policy updated in 2021[9] states that "We will manage our asset systems to deliver our purpose and objectives efficiently and safely, achieving performance within defined risk levels." Of particular significance it states that we will deliver this by:

- Setting our service and asset performance standards in accordance with stakeholder, customer, and environmental requirements
- Regularly assessing the capability of the asset system to meet changes in performance, population growth, climate change, regulatory and legislative requirements in the short, medium, and long term
- Defining and managing service risk through regular assessments of asset health and operational resilience planning.

The process we have followed to examine asset health in the period 2025-2050 is summarised below. The review has so far completed stages one-four. Stages five and six will occur after 2025 as the plan is implemented.

*Figure 5: Asset System Resilience Appraisal process*




We have assessed the full suite of our operational asset base, through the first four stages with millions of assets analysed, ranging from individual lengths of pipe to mechanical equipment and civil engineering structures such as potable water storage points.

*Figure 6: Internal inspection of our Sultzer storage point in Norwich.*

[9] asset-management-policy.pdf (anglianwater.co.uk)

In conducting this resilience assessment of our assets we have considered a range of shocks and stresses, from those considered low impact, high probability (LIHB) events through to high impact low probability (HILP) events. Throughout the document we address as appropriate the following risks:

- Asset mechanical or structural failures
- Reservoir failure (Reservoir Act)
- Supply chain failure e.g. chemicals availability
- Power supply outage to the site
- Flooding from rivers, coastline
- Deliberate attack, physical or cyber
- Long-term outage of water treatment works (due to for instance HILP events such as fire or plane crash)
- Raw water contamination of aquifers

## Customers support a long-term focus on asset maintenance and resilience

We have actively sought the views of current and future customers on asset health and summarised our findings in our Customer Synthesis document. Our research has shown that this is an area where participants in qualitative research and engagement activities have difficulty commenting. There is a widespread feeling that it is our role to determine appropriate levels of investment, drawing on our expert understanding of our assets. However, there is strong support for the company planning ahead and maintaining and investing in infrastructure, in order to safeguard the service and prevent costs storing up for the future. Investing in infrastructure and good stewardship of assets is seen as a core responsibility of the company.

In the PR19 Willingness to Pay survey, 83% of household customers (n=1353) and 80% of non-household customers (n=500) indicate that they strongly agree or tend to agree with statements concerning the pro-active replacement of pipes and sewers to avoid storing up problems for future generations, and the same percentage agree that it is important to ensure there is spare capacity in the system to deal with problems like extreme floods, power outages, and long periods of drought.

Willingness to pay studies since PR14 have consistently found higher willingness to pay to protect current performance and avoid decreases in service levels than for equivalent increases in service, known as ‘loss aversion’.

In a specific focus group with 174 customers from our online community in 2023 the findings were:

**Maintain assets regularly** - the overall consensus (92%) is that we should invest and act now on maintaining both general assets and assets vulnerable to climate change to avoid potential future disruption, water loss and higher costs of repairing broken assets later down the line.

**Educate about the issue** - maintaining assets is something 84% of customers are willing to pay around 5-10% more for per year in their bills and customers are more likely to be accepting of this if they're aware of the consequences that might occur if assets are left to deteriorate.

**Focus on climate vulnerable assets** - customers are also open to investment in priority areas, such as assets and mains vulnerable to climate change. It's good to start somewhere and have a specific focus on particular assets that need it.

Research we completed into relative customer priorities conducted with the online community also shows that customers do want investment for the future. When we shared a mix of improvements to both maintain assets and protect for the future at an increased cost of £21 per household over the AMP, more than two thirds (65%) of customers felt that this proposal was acceptable. Customers do, however, strike a balance when shown a mix of options trading off service and environmental improvement, short and long term. It is a complex choice which is influenced by overall cost and affordability. The wider work conducted on priorities showed customers chose a mixed programme of investment, resulting in a £12 p.a. increase, which included a mix of short- and long-term investments, with some that were environmentally driven. Customers felt that if a priority is needed for asset maintenance or replacement then assets vulnerable to climate change seems the sensible place to focus .

## Current assets

Our view of current assets is updated each five years to reflect the investment completed in previous periods such as new assets built, changes in network connectivity made to reduce the number of customers supplied by a single source and plans to abandon certain Water Treatment Works as abstraction licences change over time. It's also updated to reflect changes in the built environment around our assets, for example where an existing pipe was previously in farmland but has now had a new housing development or railway built above it.

We have estimated the Gross Modern Equivalent Asset Value (replacement cost) of each of our current major asset classes below:

*Table 2: Gross Modern Equivalent Asset Values.*

| Asset Class | | Quantities 2023 APR | | 2021 GMEAV (22/23 £m) |
|---|---|---|---|---|
| **Assets with deterioration models in this report** | | | | |
| Pipelines | Treated water mains | 39,248 km | £ | 9,776.0 |
| | Gravity sewers | 72,440 km | £ | 37,450.3 |
| | Rising mains | 4,844 km | £ | 1,752.2 |
| Treatment | Water treatment works | 131 | £ | 1,943.7 |
| | Water recycling centres | 1,131 | £ | 7,130.6 |
| | Bioresources | 32 | £ | 567.0 |
| Pumping | Boosters | 314 | £ | 264.6 |
| | Sewage pumping stations | 6,266 | £ | 2,299.6 |
| Storage | Water Storage points | 380 | £ | 871.0 |
| **Assets without deterioration models in this report** | | | | |
| | River Intakes | 16 | £ | 129.2 |
| | Raw Water Pumping stations | 10 | £ | 88.0 |
| | Raw water aqueducts | 721 km | £ | 574.9 |
| | Boreholes | 497 | £ | 308.5 |
| | Water Meters | 1,982,979 | £ | 828.6 |
| | Dams and impounding reservoirs | 10 | £ | 570.1 |
| | Other Sewer Structures | 585 CSOs** | £ | 333.4 |
| | Other mains | 2,245,726 Nr | £ | 3,104.1 |
| | Balancing Lakes & Tanks | 195 | £ | 205.7 |
| | | | **£** | **68,197.4** |

*NB does not cover impounding reservoir new build (for comparison the new proposed Fens Reservoir alone is estimated to cost £2.2bn)
** further value for CSOs included under other asset types

As explained in the Board Assurance Statement accompanying our PR24 plan, the company risk register was recently updated to include key, principal risk areas with risk appetite statements with accountability for each assigned to a member of our Management Board. One of those principal risk areas is Asset Infrastructure:

| Principal Risk Area | Risk Appetite Statement | Example (What does this mean?) |
|---|---|---|
| 9. Asset Infrastructure | We have an open risk appetite for asset infrastructure risk with the **exception** of impacts to our critical assets, reservoirs or processes that carry a high risk which is cautious. We will seek to reduce both the likelihood and impact of asset failure through long-term planning, maintenance, management and protection. | We will mitigate risks to the lowest level with regard to our critical assets i.e. where an asset would significantly interrupt a high percentage of customers in our region or there are safety issues. However, the extent of our mitigation for non- critical assets will be reduced i.e. may be subject to a time specific maintenance schedule. |

In essence, our risk appetite is calibrated to the criticality of the assets concerned and the performance risks they pose. As an example of our risk management approach for current assets, we have invested to replace bulk chlorine systems at our largest water treatment works, replacing them with state-of-the-art disinfection technology that is less vulnerable to supply chain shocks if critical chemical supplies are threatened, and simultaneously reduces safety risk to staff and local residents.

## Future assets

The investment we make today in enhancing the service provided to customers will add to the forward-looking maintenance requirements in the medium and long term. This will take the form of both operational activity like routine servicing and inspections, as well as capital maintenance replacing end-of-life short lived assets such as pumps, and repairing longer life assets such as burst mains. At PR09, PR14, and PR19 we analysed 5-10 year horizons to predict future asset maintenance needs and therefore the future maintenance needs of future assets still planned or under construction were a less important factor in that analysis.

Through our standard delivery processes, the resilience of future assets to climate change is reviewed via mandatory resilience tests carried out in the design phase and presented to decision making groups.

We also predict likely future maintenance costs via our Whole Life Cost calculation using ‘repeat capex’ at intervals based on predicted asset lives, and use this in decision making for approval of investments.

The analysis shown in this ASRAP represents a review of the capital maintenance needs of existing assets already in operation only. Looking ahead over longer periods in this report we need to consider the increased demands for recurring maintenance needs of assets we haven’t yet built such as new treatment technologies required to improve river water quality. Many of these assets required to achieve stretching levels of environmental improvement are likely to be technologically complex to achieve strict permitted quantities of chemicals such as phosphorous, often using mechanical and electrical systems such as automatic screens pumps or aerators, control systems, or chemical dosing equipment. All of these assets will require regular repair or replacement for wear and tear, as they operate in harsh environments.

Future capital maintenance needs will be informed by both growth in the asset base required to serve a growing population and need to meet the rising demands of a changing climate. This assessment supports the direction of travel discussed at previous reviews for the need for forward looking approaches to capital maintenance for AMP8 and beyond.

# Forecast performance of current assets

## 1 Forecast risk of asset mechanical or structural failure

In this section we explain the Asset System Resilience Appraisal stages followed, and then provide the results split by asset class.

**Stage 1 – understand context**

What is the current condition of our systems and what is changing now that will impact the resilience of the asset ecosystem (climate, operational strategy etc)

***Historic regulatory reporting of asset health measures***

We report annually on measures of asset health that are used by regulators to apply rewards or penalties. Below we have summarised four asset health measures that have remained consistent since 2005 and show how we have performed against them. In the past these were referred to as sub-measures of the 'serviceability' measures, whereas now they are referred to as asset health performance commitments:

*Table 3: past performance against regulatory asset health measures.*

| Measure | AMP4 | AMP5 | AMP6 | 2022-23 (actual) | AMP7 (forecast) |
|---|---|---|---|---|---|
| **Mains bursts*** | Stable | Stable | Met | Not met | Met |
| **Sewer collapses*** | Stable | Stable | Met | Met | Met |
| **Unplanned outage at WTW** | n/a | n/a | n/a | Met | Met |
| **Treatment works compliance** | Stable | Stable | Met | Not met | Not met |

*we made the case to Ofwat in response to their consultation on Assessing Base Costs at PR24 that the measures of mains repairs and sewer collapses are not suitable measures of asset health, since mains repairs can be managed via operational improvements such as pressure management in the short term, and collapses are defined as the sum of collapses of gravity sewers and burst sewer rising mains, with the incidents only reportable if they disrupt service to customers. This encourages rapid response to structural failure, but masks the extent of the issue of asset condition.

As part of Stage 1 we collate the actual failure history data that has been reported in the regulatory measures at an asset level where possible. We also extract updated master asset data from corporate systems to understand how the asset base has evolved since the last appraisal. For instance, we collate material and diameter data for new pipelines installed, as well as kW power rating and flowrate of new pumps installed to enhancement treatment on our sites.

Within Stage 1 we also review changes that we anticipate will affect future performance. For PR24 the main changes we recorded were:

- Increasing urbanisation – historic pipe assets that were previously analysed as having low risk of flooding as they were in a field have since had new housing or other developments nearby, and therefore will present a changed risk profile in our analysis

- Effects of climate change – changing weather patterns will affect asset deterioration, therefore we commissioned new research into the effects of this
- Water Resource Management – changes to the sources and chemistry of water conveyed in our network which have the potential to affect deterioration rates, therefore we commissioned research into the effects of this

## Stage 2 – forecast change

Using analytical models to develop scenarios for how our assets might change or deteriorate in the future

***Infrastructure forecasts***

We model the deterioration of water mains, gravity sewers and rising mains using statistical deterioration models which we **update with actual recorded failure data every five years** prior to each business plan. The models are built from data on past asset failures and predictors of failure such as age, diameter, soil type, pressure, and property density. Each of these variables has been statistically tested for significance and found to correlate well. For water mains we have five separate models for different pipe materials. The pipe material of gravity sewers and rising mains is taken into account using different material coefficients within the gravity sewer and rising main models.

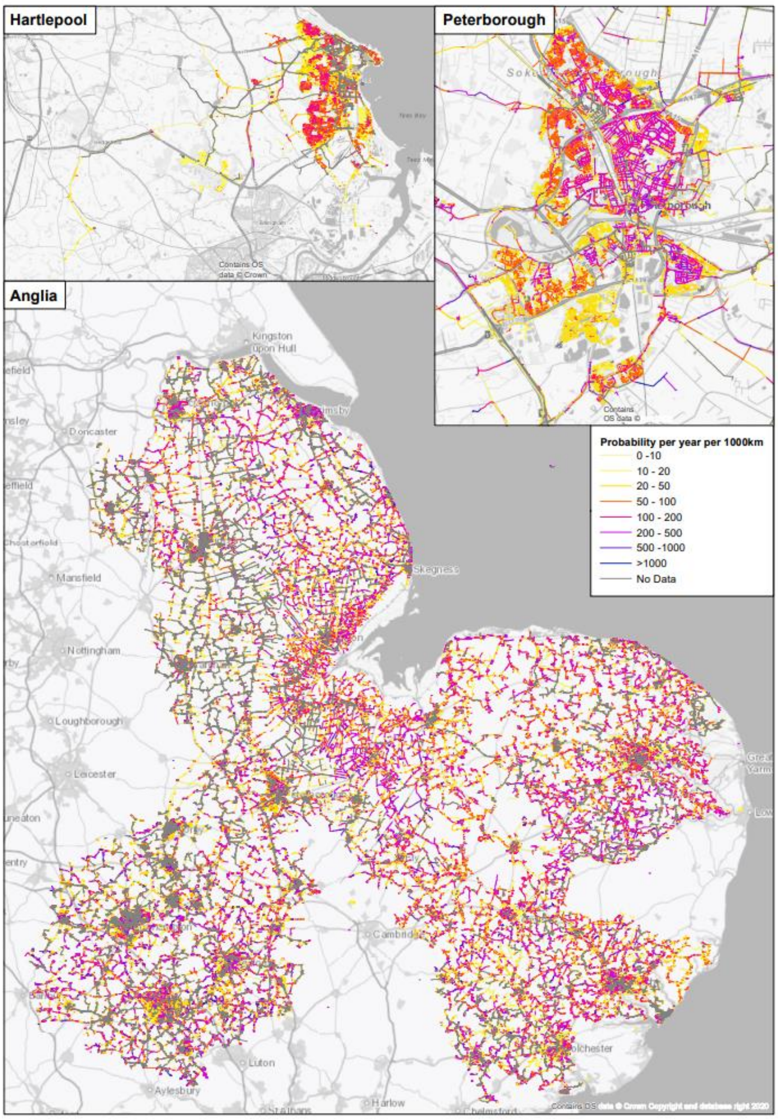
Each update of the models involves updating the asset database by adding new pipes and removing redundant pipes, incorporating new failure data from the last five years, and collating the attribute data for the predictors of failure for each pipe. The statistical models are rebuilt and applied to the current asset base.

The deterioration models provide the failure rate for each pipe in 2022 and a deterioration factor is then applied to predict the number of failures in future years. The predicted failure rates for each water main and rising main are tuned to take account of the number of actual failures of each pipe, and a compensation factor is applied to all pipes to ensure the total number of predicted failures across each asset type equals the average number of actual failures over the last five years.

We are continually looking for additional variables that can affect asset failure to make our models more accurate; most recently we have included new details of the hardness and pH of water conveyed through our water mains, as recent research by UKWIR found that this can affect the predicted likelihood of failures on certain pipe materials. For PR24 our analysis now uses climate change forecasts to generate uplifts to the expected failure rate of water mains. This is discussed more in section 1.1 below.

As an example of the outputs of the analysis, the image below shows the likelihood of failure of each treated water supply pipe mapped across our region, with examples shown in more detail for Peterborough and Hartlepool:

*Figure 7: Plot of likelihood of failure in water network assets*




The likelihood of failure is not constant; the models show a change in likelihood year on year as the asset ages and conditions change. The likelihood data gives us our prediction of the probability of failure for Asset Health Performance Commitments such as the risk of mains bursts, sewer collapses, and rising main bursts.

***Non-infrastructure forecasts***

Our non-infrastructure Asset+ Risk Modelling system is used to predict the expected number of failures of assets and the number of service failures caused by each asset. This system was designed and built specifically for us by our IT partners and we have recently completed a review of available technologies on the market that could replace it. Currently none are available with the same level of capability. Assets are modelled at the plant item level which is the lowest level in our asset hierarchy and SAP asset database. Examples of modelled plant items are pumps, motors and starters.

Every treatment and pumping site has had a unique model built for it, representing the individual process related plant items that make up the site. The plant items are arranged in failure modes such as ‘No Chlorine Dosing’ which contains all the plant items that could cause there to be no chlorine dosing if they were to fail. Failure modes are used to analyse the duty and standby arrangement of the plant items, so failure of a plant item can only lead to a service failure if the plant item has no working standby.

Each plant item has a deterioration model assigned to it from our library of 332 unique deterioration models. These are used to predict the number of plant item failures. Each type of asset also has a downtime model to represent the period when an asset would be repaired.

As explained below the failure rate is dependent on many variables over time including asset age and therefore effectively forecasts remaining economic asset life at an individual asset level. The outputs of the deterioration models are fed into Copperleaf.

## Stage 3 – assess service impacts

Using our hydraulic and process models to develop scenarios for how asset failures could impact service, and understand how customers value the change

***Infrastructure impacts***

The service impact of infrastructure asset failure is determined for each asset using modelling tools that tell us the number of service failures caused by each asset when it fails. Consequence is calculated using our understanding of system operational usage, system connectivity, operational emergency response capability, interactions with and crossing of other infrastructure, as well as topography.

Our hydraulic models are used to determine the number of properties that would be impacted by failure of each asset. Each pipe is failed one at a time to model how many properties would experience an interruption to supply, low pressure or aesthetic issue. Flood route mapping is used to model the flooding and pollution caused when sewers, rising mains and large diameter water mains fail. For each pipe a volume of flood water is calculated, and the location of its escape determined. The overland route of the discharge is generated, and the impact determined in terms of the number of properties and roads flooded and water courses polluted. All consequence modelling was updated for PR24.

***Non-infrastructure impacts***

**The risk models are refreshed before each business plan submission** using master asset data from SAP. This includes updating asset installation dates, the number of properties supplied, WRC consents, and WRC flow and loads. The models are re-simulated and WRC models re-calibrated so that the modelled effluent concentrations with no failed assets match with measured sample data.

Using the deterioration and downtime models, the Risk Modelling system creates a failure timeline for each plant item and compares the downtimes of all plant items in each failure mode to see when plant item failures coincide to cause the failure mode to occur. Each failure mode occurrence is attributed to an individual plant item. This process is performed in 50,000 Monte Carlo simulations over a 25-year period. Risk Modelling then counts the number of failure modes that have occurred each year due to each plant item and applies a service failure likelihood to determine the expected number of service failures. These likelihoods were estimated by our process experts using operational knowledge and historic experience. The Water Recycling Centre (WRC) models include process removal calculations to model the impact of asset failure on final effluent quality.

***Valuation of impacts***

The service impacts are monetised using our Six Capitals Value Framework which enables the wider environmental and social value of different assets to be compared on a like for like basis. The monetised risks include the private costs to our company such as the remedial costs of an incident like providing bottled water, but also societal costs using customer research to assign relative value based on willingness to pay to avoid those incidents. The Value Framework includes Performance Commitments such as pollutions and interruptions to supply, but also measures of wider environmental and social value such as the risk of:

- low pressure
- odour
- visual amenity
- traffic disruption
- public and employee safety

## Stage 4 – develop the investment strategy

Select a sustainable investment strategy over the long term including mitigation strategies

We have forecast the risk of asset failures since PR09 using a range of digital tools and have constantly evolved our use of these tools to improve our asset knowledge. Recently we moved to the use of the Copperleaf C55™ Predictive Analytics module which allows us to test multiple strategies to forecast the long-term maintenance needs of our assets based on economics and risk. The tool enables visualisation of future asset demands and development of investment strategies to smooth out expenditure and resource requirements. Previously these analyses were only completed over 5 or 10 years but using the new tool we have been able to analyse the whole asset system 25 years into the future. Some key features of the new analysis compared to the previous analysis are presented below:

| PR19 deterioration modelling | PR24 Predictive Analytics |
| --- | --- |
| Circa 90% of the asset base analysed | Transferred sewers added to the analysis |
| Asset risk analysis completed over 5-10 years | Asset risk analysis completed over 25-60 years |
| Overall results inferred from small % of pipes | Results obtained by analysing all pipes |
| Climate change not considered | Climate change uplift applied to water mains |
| Results inform Capital Maintenance only | Results inform Capital Maintenance, 'What Base Buys', and enhancement cases |

We have tested multiple different maintenance strategy scenarios, understanding contributing factors to forecasts such as changing operational use with the introduction of our strategic grid, the impact of technological advances like smart systems, and the effects of climate change on soil movement. Our forecasts for non-infrastructure treatment and mechanical assets are made over 25 years, whereas some of our forecasts for infrastructure assets (pipelines) are made over longer periods. The forecast risk is not only used for long term planning of maintenance expenditure, but also as the basis of incident response tools in our operational teams as well as informing alarm priority in the monitoring of telemetry systems.

***Intervention Costing***

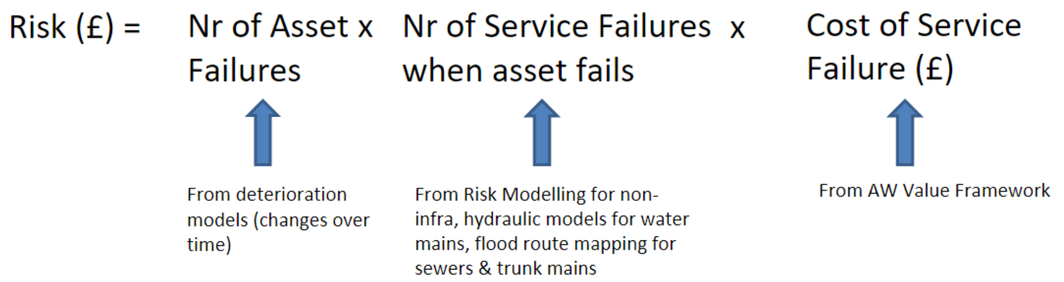
The intervention costs for the modelled assets were calculated using our cost models in C55. These are based on the actual costs of previous interventions. Some assets have multiple intervention types such as replacement and refurbishment. Large non-infrastructure assets that can be refurbished have repeat refurbishment rules that are specific to the type of asset. They define the timing and number of refurbishments that can take place before the asset has to be replaced.

***Optimisation of Interventions***

We have several tools and systems that are used to model asset deterioration and the consequence of asset failure, primarily 'Copperleaf Predictive Analytics' and 'Asset+ Risk Modelling'. Together these tools allow the application of a risk-based forward-looking planning approach. They enable the risk carried by individual assets to be understood and allow decisions to be made on the optimum interventions to manage asset performance and service to customers.

Our optimisation tools compare the cost of the maintenance intervention with the monetised risk, underpinned by the following equation which generates a monetised risk for each asset:

*Figure 8: Monetised risk equation*




We have used Predictive Analytics to investigate the long-term performance of our assets. The optimisation engine uses the monetised risks, intervention costs and optimisation constraints to select an optimal mix of assets for renewal. Constraints can be financial or performance based, although the optimisations presented in here all used financial constraints.

The optimiser will select a different set of assets for intervention depending on the performance objectives set for the same financial constraint. For example, different pipes would be selected if maximising value was the objective, compared to selection being based on maximising the length of pipe renewed.

The performance prediction is therefore heavily dependent on the specification of the optimisation run. We have run optimisations to achieve the best value set of interventions on the basis that the

PR24 methodology requires us to consider social and environmental value and we have used our six capitals value framework to do that in the analysis.

We have used a consistent format to present the findings of our optimisations, with baseline performance levels in the absence of maintenance spend shown in red, and residual post investment levels in blue. In some of the graphs, the modelled baseline and residual numbers have been indexed to historic performance to allow comparison.

We have also considered mitigation strategies such as reallocating funding to increase expenditure above current levels, or additional operational interventions for that asset class. These are explained in the relevant section.

In the sub-sections below we describe the outputs of Stage 4 for each asset type.

## 1.1 Treated Water Mains

As explained above, we have completed deterioration modelling in previous price reviews in line with the UKWIR methodology Capital Maintenance Planning: A Common Framework[10].

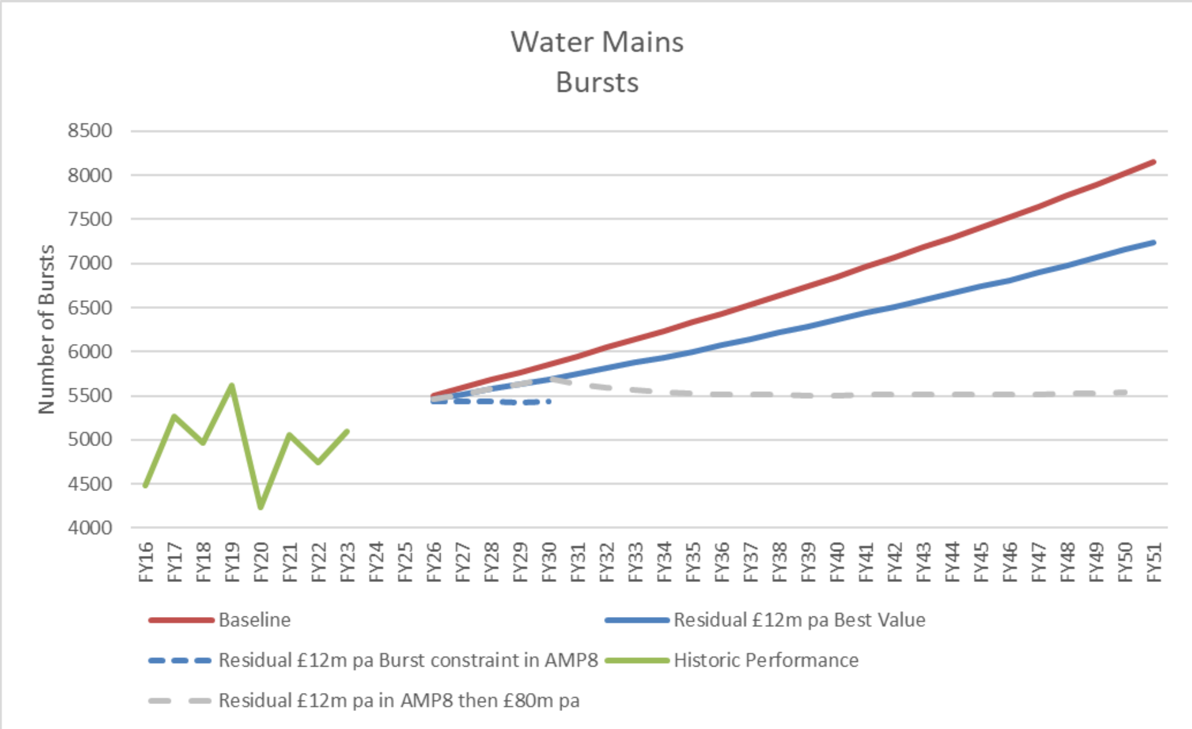
***Deterioration modelling***

During AMP7 the average annual spend for water mains capital maintenance is £12m per annum. We have compared the actual bursts on treated water mains in the past five years with the predictions we made in the last round of deterioration modelling at PR19 and found that the **top 20 per cent of length identified as high risk in 2017 has accounted for 56 per cent of the actual bursts until now**, with the bottom 20 per cent accounting for just 2 per cent. This shows a high degree of accuracy of prediction in this asset class. As explained previously, all the actual failure data has been fed into the model to refine the accuracy of future predictions.

We have tested a continuation of the AMP7 run rate into AMP8. The choice of optimisation priorities affects the interventions the optimiser selects and the residual performance. This can be seen in the solid and dotted blue lines in the graph below. The solid blue line shows the number of residual bursts with expenditure of £12m per annum when the optimiser finds the best value solution across all six capitals value measures. The number of bursts increases because the optimiser maximises value by selecting pipes for renewal that result in the greatest reduction in interruptions to supply instead of targeting burst reduction. The dotted blue line shows that bursts can theoretically be kept constant in AMP8 with expenditure of £12m per annum if the number of bursts is constrained to remain stable. The optimiser models the burst target while maximising value but achieves a smaller reduction in interruptions to supply than in the optimisation with no burst constraint. In 2030 the unplanned interruptions (>3 hrs) residual would be 54 seconds per property higher when the aim is to keep bursts stable than when the aim is to maximise value. This illustrates the trade off in decision making between performance commitments in the selection of assets to prioritise for proactive maintenance.

The dotted grey line shows that after AMP8, expenditure of £80m per annum would be required to keep bursts at the current level if targeting the highest value pipes and not constraining on bursts. There will be a severe deterioration in performance if expenditure is not increased significantly after AMP8.

[10] https://ukwir.org/eng/reports/02-RG-05-3/66808/Capital-Maintenance-Planning-A-Common-Framework-Volume-1-Overview




The modelled numbers of bursts have not been indexed.

For PR24 Ofwat have introduced a new data table (CW20) relating to water mains condition. We have populated the data as requested, however, we note that the method used to derive condition is based on backwards looking failure history, and therefore is subject to the same distortions as the Performance Commitment with burst rate affected by pressure management schemes effectively extending asset life. Despite this our analysis shows a marginal worsening of asset condition for the majority of the asset base (<320mm diameter) as defined by these tables since it was last measured at PR09, which is in line with the above deterioration modelling. The change in condition for larger diameter mains is within a margin of error meaning the analysis is inconclusive.

On this basis we do not request an uplift in base maintenance of water mains in AMP8, instead refining our selection of mains for rehabilitation and investing in operational improvements as described below.

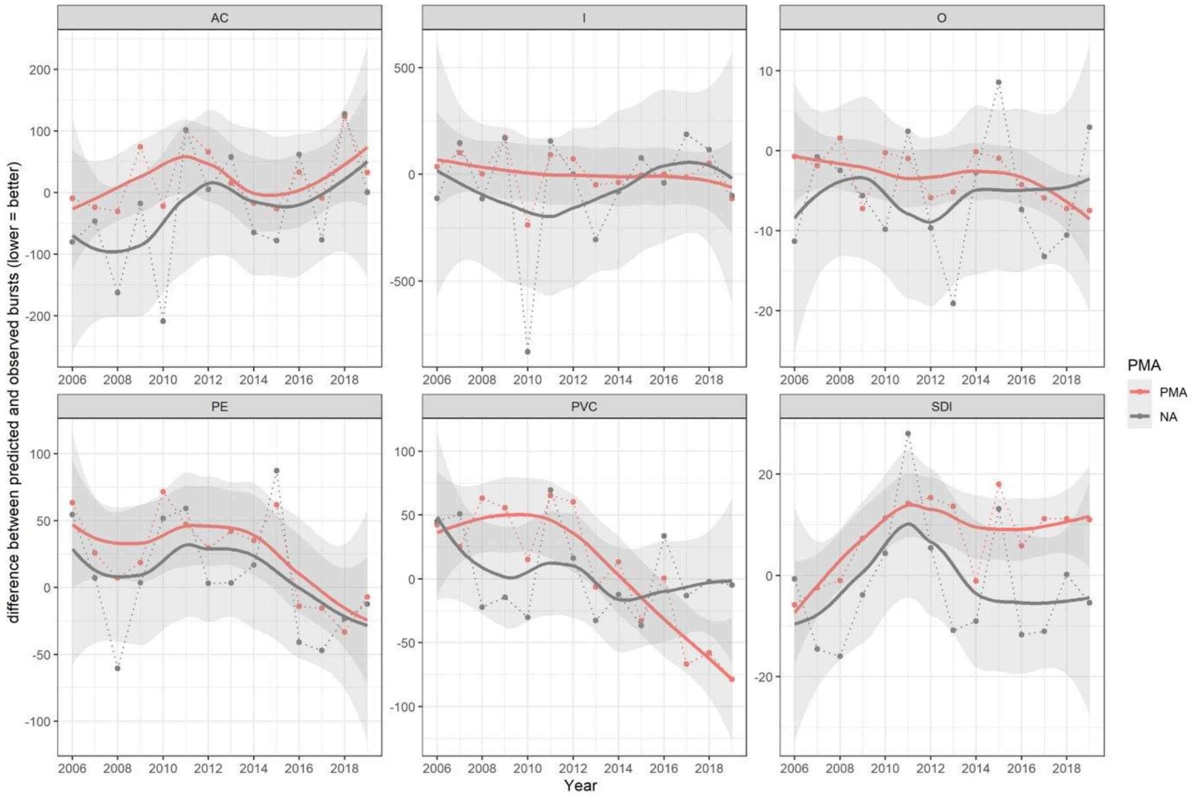
**Mitigation actions**

In our delivery teams we have developed our analytic capabilities to better target investment on the sections of main which burst more frequently and cause the greatest customer impact, using a tool known as WISPA (Water Infrastructure Serviceability Performance Assessment). This has resulted in smaller schemes which are shorter lengths but still result in the same reduction in burst frequency and consequential reduction in customer impact along with a reduction in scheme duration and customer disruption through activities in the highway. This has impacted on the length of mains replaced but not the total benefit of the schemes chosen.

Further to this, and to ensure we are delivering the key outcomes that our customers value, such as maintaining our frontier levels of leakage, reducing burst mains (and consequentially supply interruptions) and developing our smart network capabilities, we have heavily invested in pressure management as our principal AMP7 strategy for the delivery of customer service and our key performance commitments. This links to our strategy of development of safe, smart water systems across our region. In previous AMPs we have developed simple pressure management systems, during this AMP we are rolling out advanced pressure management systems with smart controllers achieving more stable pressures in the area. We have so far installed 144 new pressure management systems and uprated a further 201 to advanced pressure management systems. This is against an original plan for 2025-2030 of 75.

As part of our post investment benefits review, we have analysed the observed bursts in pressure managed areas (PMAs) to confirm if the intended benefit of the schemes (a reduction in burst frequency) has been achieved. The data presented below takes failure data from 2006 to 2019 and compares the predicted failures from our WISPA model with observed failures by material type. It is clear from this that pressure management has been our main strategy for burst reduction and has been effective in helping us achieve our performance commitment targets for mains bursts over this period, in particular for PVC and iron mains:

*Figure 9: Observed bursts vs predicted bursts for Pressure Managed Areas (PMAs)*




The reason that the red lines begin above the grey lines is that the areas selected for pressure management are those with the highest burst rates. In the next AMP 2025-2030 we will see fewer new installations of pressure management system as we will have completed the vast majority of our distribution zones. However, we will continue to optimise those systems.

***Climate modelling***

As part of our Climate Adaptation Report 2020[11] we set out the risks we face from climate change and explained that we were improving our understanding of the risks to water networks associated with high temperatures and low rainfall, looking ahead to the adverse common reference scenario and using a less optimistic scenario of a potential 4°C rise in global temperatures (#fitforfour).

[11] climate-change-adaptation-report-2020.pdf (anglianwater.co.uk)

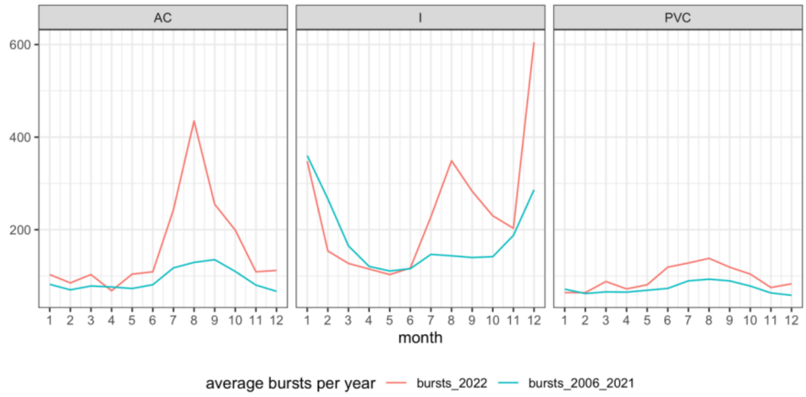
For PR24 we commissioned a study into the effect of climate change on water mains. The main findings were that:

- bursts on iron mains will initially reduce due to warmer winters
- bursts on asbestos cement (AC), iron and PVC mains will increase due to hotter, drier summers
- In the short term most bursts will occur in the summer.

At the start of this appraisal, we were uncertain of the impact climate change would have on our infrastructure. Now, we have the ability to pinpoint the pipes that are most vulnerable to climate change, enabling highly targeted tactical interventions in the short term. In addition, we now have evidence to inform long term replacement programs which maximise the return on investment of our capital expenditure by preventing future failures from occurring.

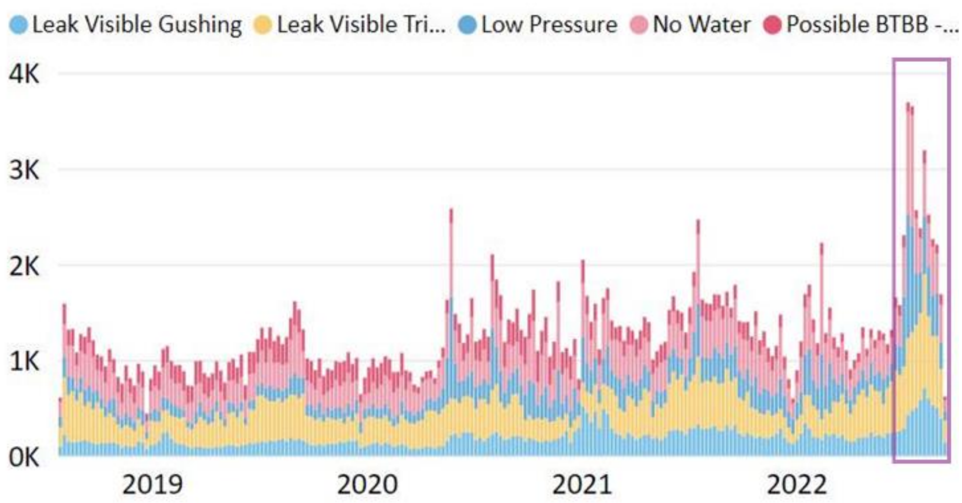
The graphs below show the response of the most climate vulnerable pipes (AC, iron and PVC) to the extreme summer weather of 2022. The red lines show the bursts per month in 2022 and the blue lines show the average bursts per month between 2006 and 2021. There is a clear elevation of bursts in AC and iron mains in particular.

*Figure 10: 2022 bursts vs long term average*




In our APR23 we reported missing the Performance Commitment Level for supply interruptions, mains bursts and leakage. With the weather conditions we experienced, we saw dramatic impacts on service to customers, with an 80% increase in call volumes during July 2022 when compared to the 3 year average to our contact centre relating to low pressure, interruptions to supply, leakage and mains bursts:

*Figure 11: Inbound customer contacts summer 2022*




During this period our company incident room was open for 6 weeks. According to the climate forecasts available today, temperatures and rainfall levels that we experienced in 2022 become average conditions by the 2060s, meaning that this level of disruption would be normal.

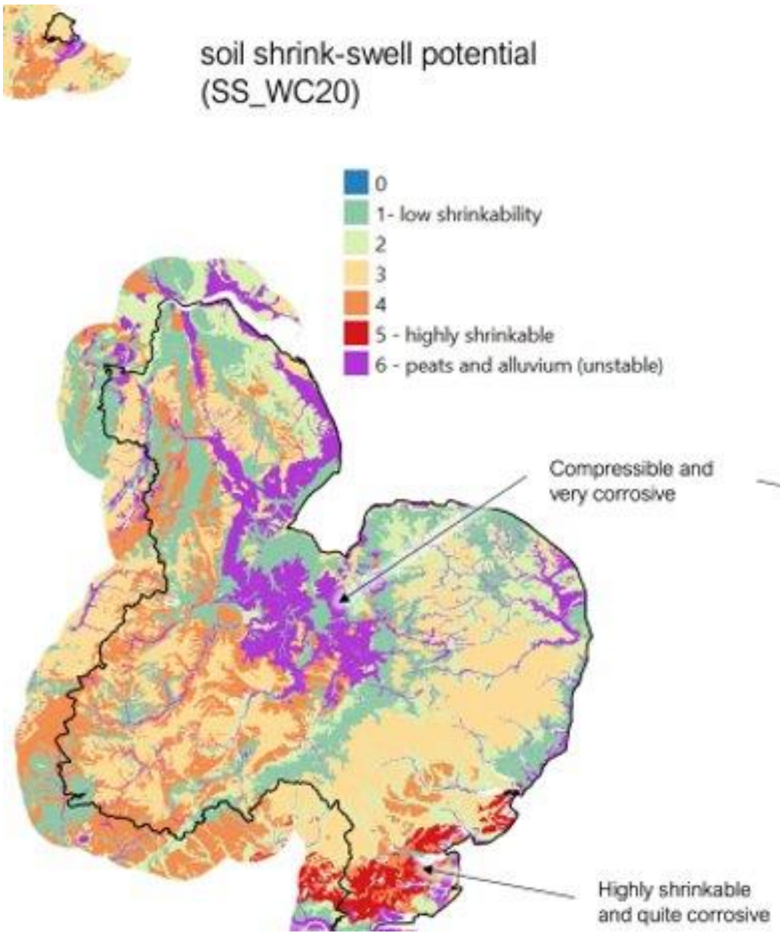
As a result of the climate modelling study, we have been able to come up with a clear definition of our climate vulnerable mains (CVMs), of which there are around 8,000km in our network. These are pipes that are predicted to prematurely fail more in future as they are particularly susceptible to the increased soil moisture deficit that will occur when summers are hotter and drier. CVMs are defined as pipes that are:

1. Made of **rigid materials** i.e. AC, PVC, cast iron, and are
2. **smaller diameters** = <320mm, and are
3. **laid in highly shrinkable soils** i.e. classification types four to six.

It is important to note that none of these three criteria is age related, and is purely a function of the physical characteristics of the asset. Our asset base is uniquely exposed to this risk because we have the highest proportion of AC mains of any English or Welsh water company at around 17%, and also the highest proportion pipes laid in highly shrinkable soils.

The map below shows soil classification type across our region indicating a particular prevalence of shrinkable soils in coastal and fenland areas unique to the Anglian region:

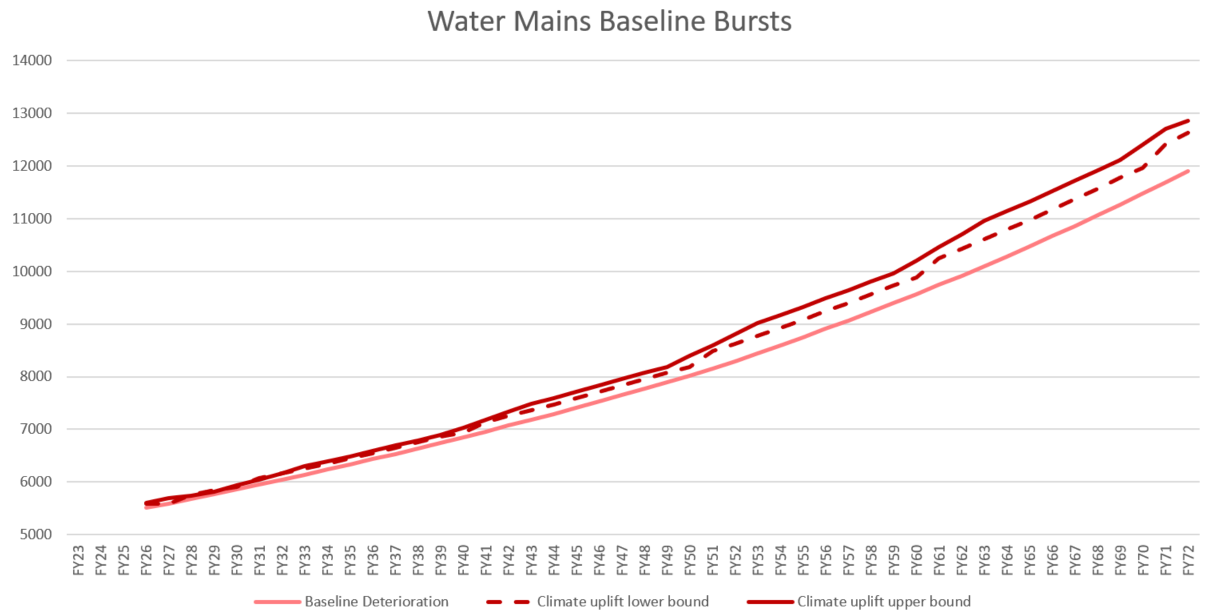
*Figure 12: Anglian Water region soil types*




The graph below shows how we believe our assessment of deterioration is likely to be affected by climate change. The blue line shows the predicted bursts caused by deterioration only after spending £12m per year, matching the analysis earlier in this chapter. The red and dashed red lines show the upper and lower bounds of the increase in predicted bursts when the effects of climate change are included. As part of the recommendations of the AMMA in 2022, Ofwat stated "*To improve its maturity in this area, Anglian Water recognised that it needs to better incorporate uncertainty into its understanding of risk of asset failure and should consider this for different timeframes to inform decision-making and planning.*" We have therefore considered two methods to derive upper and lower bounds of the climate uplift:

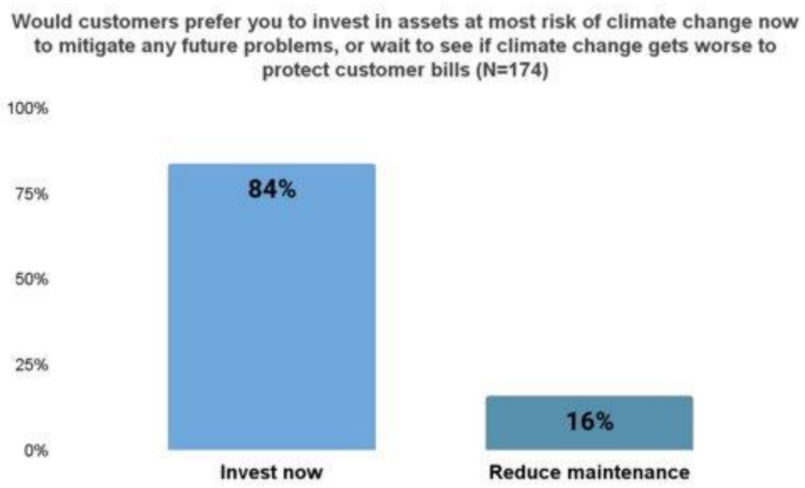
- The lower bound (red dashed) uses the research we commissioned in 2021 converted from monthly average temperatures and soil moistures into annual average increases in bursts, this therefore smooths peaks in burst rate
- The upper bound (red) shows where bursts in 2070 have been progressively uplifted to match the observed bursts in 2022. This is on the basis that the adverse Climate Change scenario RCP8.5 shows that summers like the one seen in 2022 are expected to become normal.

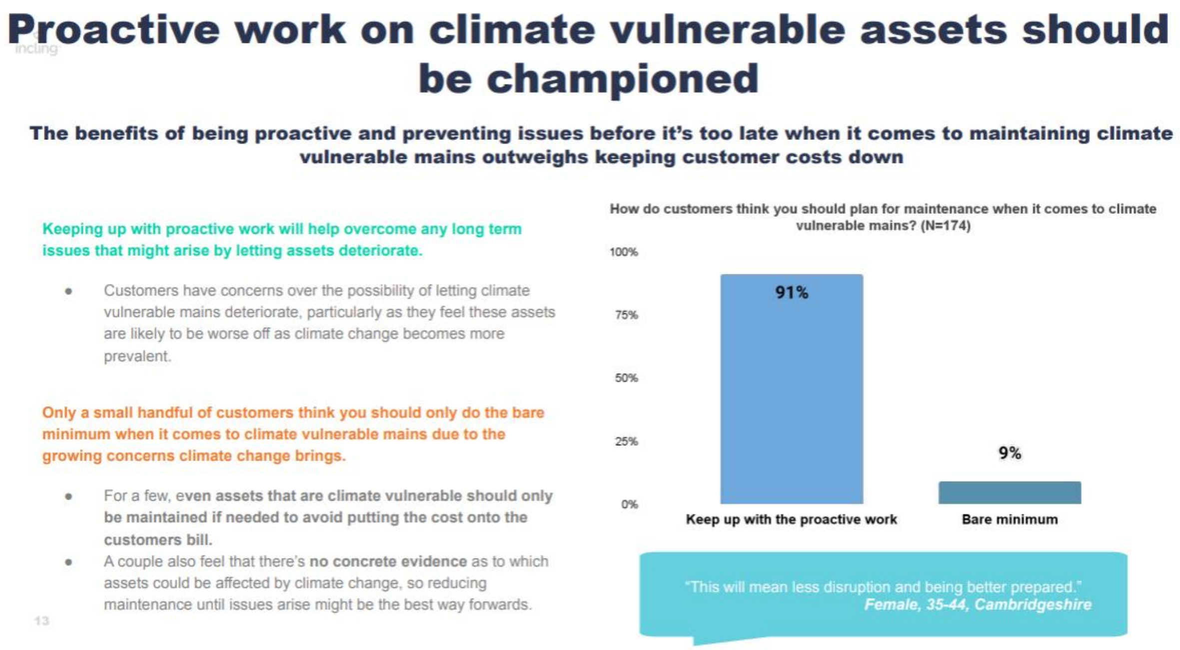
We think the lower bound underestimates the number of extra bursts that will occur because of the statistical approach taken using annual average increases that mask predicted monthly peaks in bursts in summer months, and that therefore the upper bound is a more likely picture of how bursts will increase in future.




We used multi parameter optimisations within our Copperleaf Predictive Analytics investment planning system to model the expected increase in bursts per year due to climate change in future decades. Through this analysis we tested several expenditure scenarios to see the reduction in burst rate from the upper bound to offset the climate impact. We engaged with customers to test their views on how we should address this risk, and received strong feedback that their preference was to take a proactive approach:

*Figure 13: Customer engagement results*

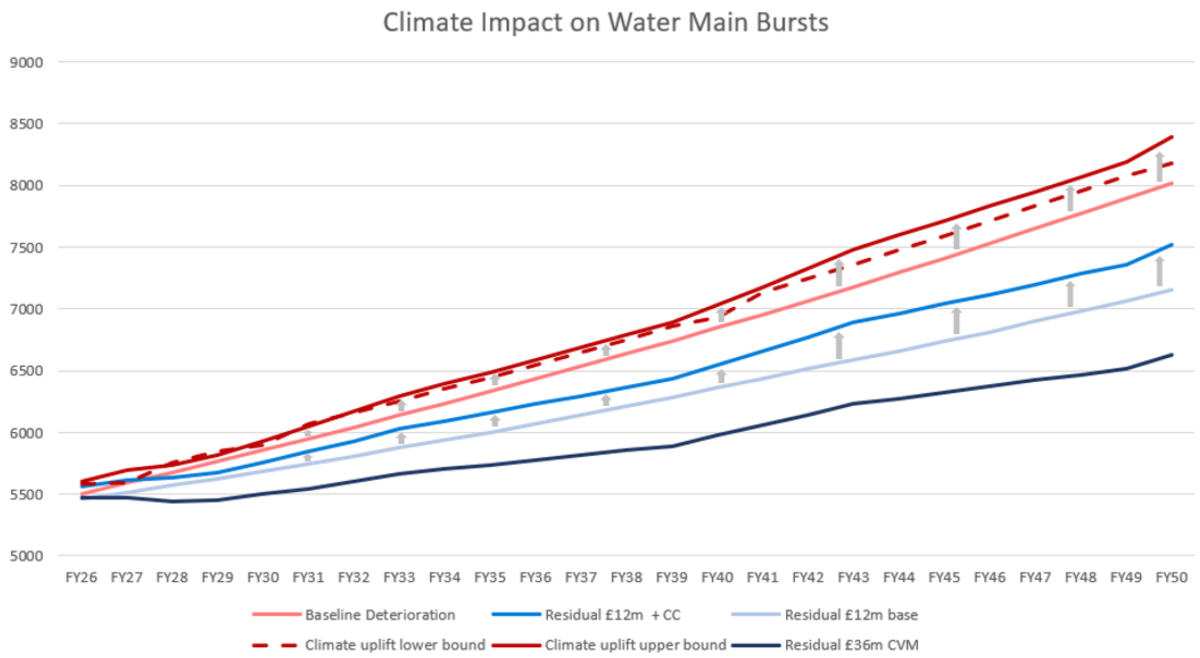





In selecting a preferred investment strategy for this issue we also considered deliverability. Rapid increases in length of mains renewed would pose a challenge for delivery teams and resourcing in our supply chain. In the period 2020-2025 we are forecasting to renew around 200km of water mains. We tested strategies that included a range of possible increases on this up to around 1,000km between 2025-2030, a 5 fold increase. We concluded in discussion with delivery teams that increases above this were simply underliverable.

On the basis of the above we selected an enhancement strategy to replace the majority (~6,000km) of Climate Vulnerable Mains, between 2025 and 2060, so that most are no longer in service at the point of the worst impacts of climate change. This represents a 4 fold increase in delivery rates in the next five years. The Resilience enhancement case appended to our PR24 plan provides more detail.

The graph below shows the climate impact on the base only spend for deterioration of £12m per year, which is then offset by the selected strategy of £36m per year spend on Climate Vulnerable Mains:




This analysis has been used to determine performance forecasts for 'what base buys' in our LTDS, and our 2030 Performance Commitment Level, which has been adjusted down from the baseline by around 390 bursts per year, recognising the impact of the investment in that period.

***Impact of water chemistry***

We are currently constructing a vast network of pipes to move water from the wettest areas in the north of our region to the driest areas in the south and east at the same time as developing new reservoir sources in Cambridgeshire and Lincolnshire. The 2017 UKWIR report on Basic Mechanisms of Bursts and Leakage concluded that chemical attack from the conveyance of soft water can greatly weaken AC mains. In order to investigate the impact of moving softer water from the north to other parts of the region, we have added water chemistry parameters to our deterioration models and added new functionality to Predictive Analytics that allows us to easily assess the effect of changing the water softness in the AC pipes. Water hardness in our region varies by source and supply zone but is typically significantly harder than other parts of the country, with the south of the region around 300mg/l. Our investigations showed that the water being transferred from the north is likely to be of a similar hardness in the short term, based on the sources available at present. The deterioration models predicted there would not be a significant impact on deterioration, with bursts on AC mains stable but it is something we will monitor in future, in particular as sample data becomes available for the new strategic reservoirs, and is something that could become more of a problem if in the longer term we were to import water from other parts of the country where water is very soft.

**Single points of failure**

Since PR09 we have been assessing single points of failure within our mains network, looking at issues such as protection of pipe bridges and crossings of other national infrastructure such as transport networks (motorways and railways) and rivers. We obtained funding at PR19 to improve resilience at high risk locations including proactively dualling existing single pipes in order that service can be maintained in the event of a failure. We have a prioritised list of single points of failure that we intend to continue to invest in to mitigate the risks of asset failure at these locations.

**Summary**

Based on the research conducted and summarised above, we do not believe that current maintenance levels are sustainable in the long term, and therefore these are marked as amber or red, meaning that increased maintenance expenditure is required beyond 2030 potentially requiring up to £80m per year. However, a start needs to be made on the significant long-term work required to ensure that service to customers can be maintained as climate change impacts water mains durability. We are therefore including an increase in mains renewal rates specifically targeted to mitigate climate effects on those assets found to be at risk of worsening climate impacts in our PR24 plans from 2025 -2030. We are also including additional investment in mitigating single points of failure. Within our LTDS document we have also scenario tested the future impacts of technology and reflected the potential benefits of these improvements to smart networks on long term performance. With these mitigations in place we believe that the mitigated forecast for the period to 2030 is stable:

| Asset class | | Unmitigated | | | Mitigated | | |
|---|---|---|---|---|---|---|---|
| | | 5 year | 10 year | 25 year | 5 year | 10 year | 25 year |
| **Pipelines** | 1.1 Treated water mains | ↘ | ↓ | ↓ | ↔ | ↘ | ↓ |

## 1.2 Gravity Sewers

***Climate modelling***

In addition to the investigation on the impact of climate on water mains, we also commissioned a preliminary investigation into the impact of weather on sewers and rising mains as it seems reasonable to expect them to also be affected. Unfortunately, the date that asset failures are recorded is currently too uncertain to quantify any relationship with weather conditions with much certainty. We tested over 100 weather variables including those with temporal lagging and thresholds. While some patterns could be found which matched with our expectations of logical failure mechanisms, the data was not sufficient for us to confidently prove any relationships to specific weather patterns. This may be because sewer collapses can take longer to be discovered and reported after the event than water mains bursts.

As a result of this investigation, we found that failure rates are higher for particular pipe materials and soils, but we have not factored these into our deterioration modelling for PR24. We are working with our internal repair teams to improve data capture to assist in future modelling work for PR29.

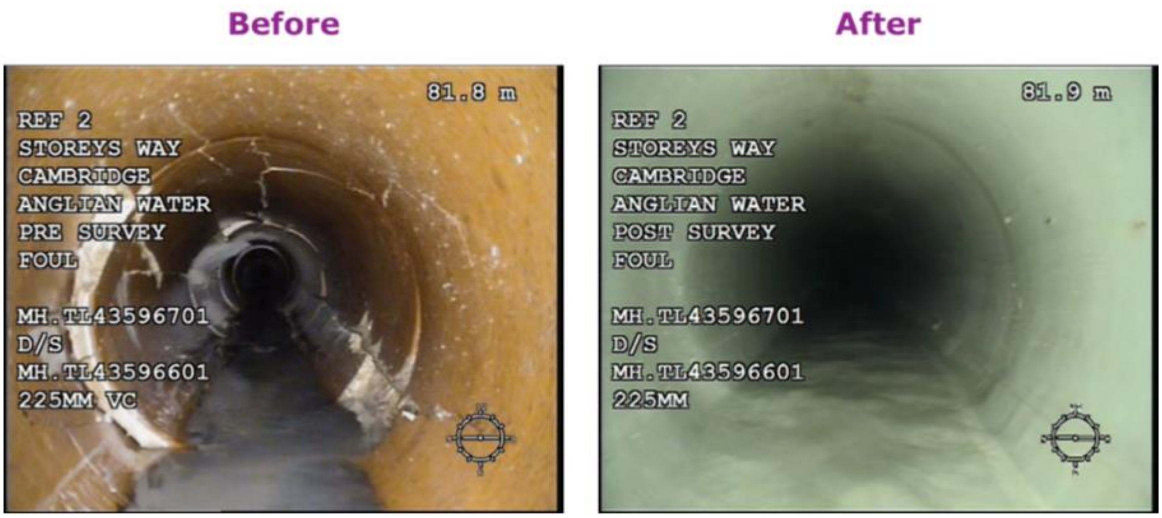
***Deterioration modelling***

Our network of 77,000km of sewers includes varying diameters and liquid types, with over 11,600 km of surface water only sewers. This includes over 30,000km of sewers adopted in 2011, for which we have worked hard to increase asset data and are therefore now able to include the majority in our analysis. Our deterioration models use various physical characteristics to predict likelihood of failure due to deterioration including installed date, material, soil type, liquid type and diameter. The average annual spend for gravity sewer capital maintenance in AMP7 is £12m. The purple dotted line in the graph below shows the residual number of collapses that this achieves. In AMP8 the proposed expenditure is £18.8m per annum achieving the residual shown in the blue line. Collapses and pollution incidents are predicted to increase in AMP8 and beyond, but internal and external sewer flooding incidents are predicted to decrease slightly.

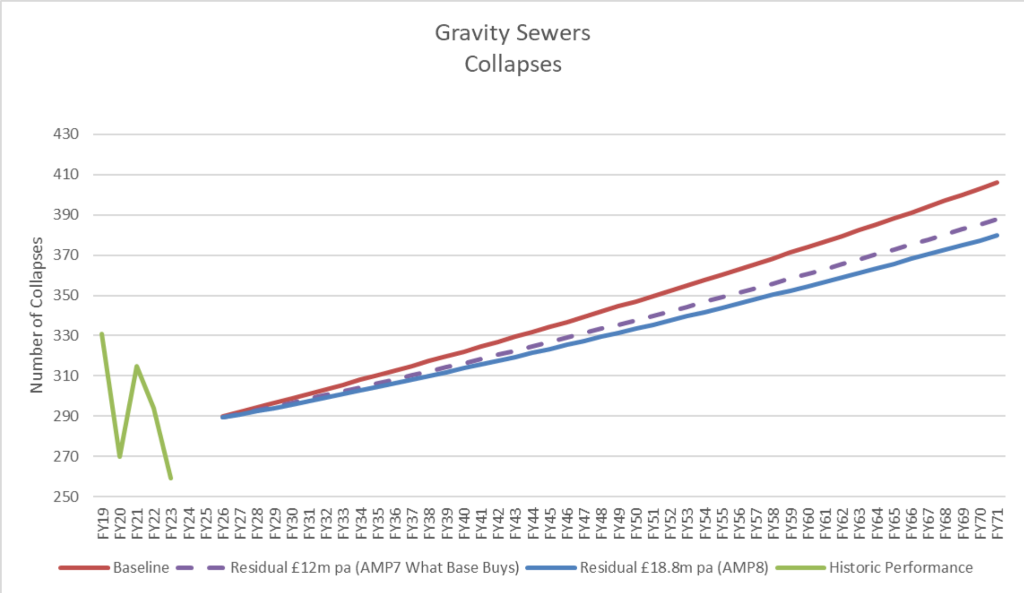
*Figure 14: Example damage caused by collapsed sewer*

Sewer collapses can be relatively minor in nature, or extremely significant engineering projects. In AMP7 we have invested over £10m to resolve a single major sewer collapse in Southend, equivalent to 10% of all planned maintenance budget for the AMP for gravity sewers. Generally, sewer maintenance work involves use of lining techniques as can be seen in this image:

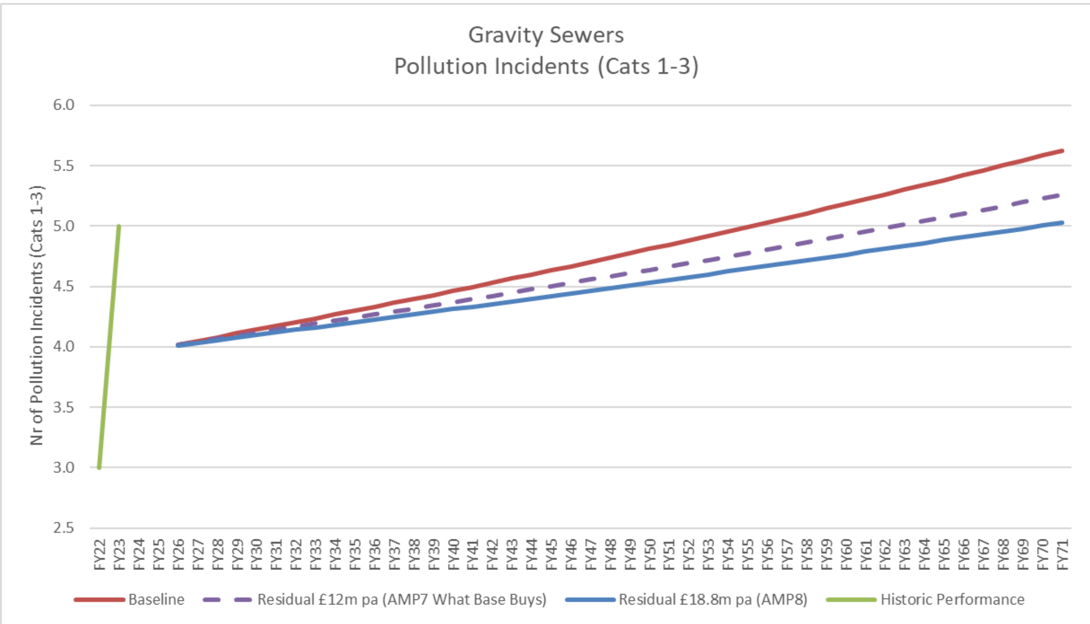
*Figure 15: Sewer lining technology photographs*

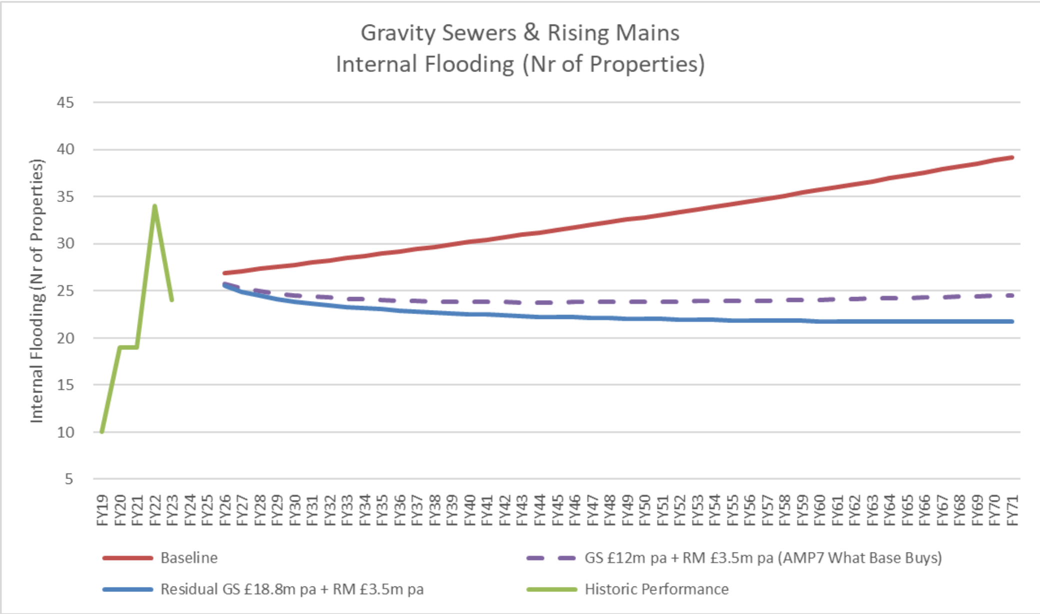


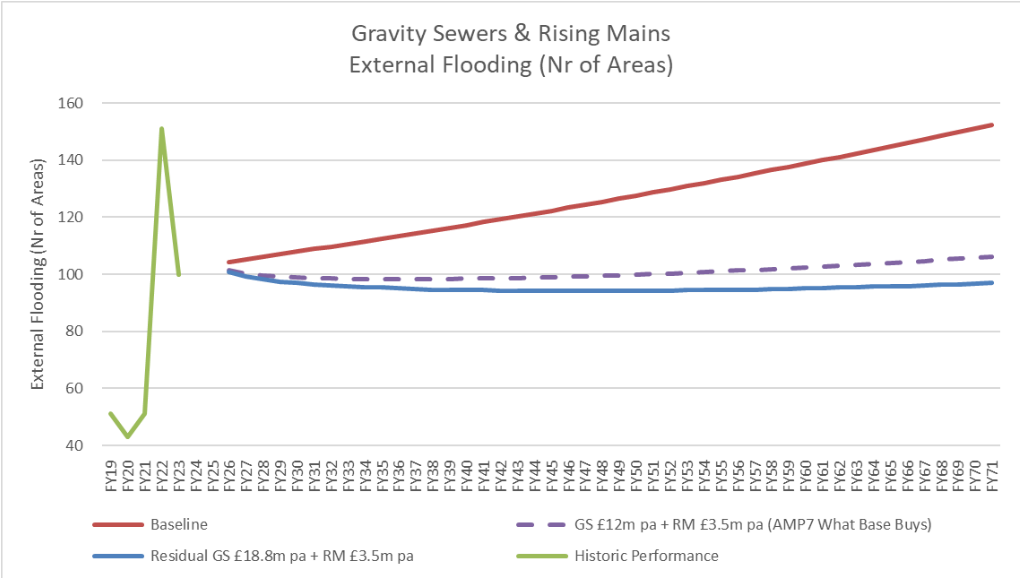

The modelled numbers in the four graphs below have been indexed.




At PR24 Ofwat have introduced a new data table asking for data on sewer asset condition (CWW21). We note that the method used to derive asset condition in this table is once again backwards looking in nature, using recorded collapse history to date. Comparison with PR09 asset condition is not possible owing to the methods used therefore conclusions cannot be drawn from this regarding changing asset condition over time.






In recent years we have identified a root cause of failure in our sewer networks as hydrogen sulphide attack of concrete sewers. This occurs at the discharge point of rising mains, where the anaerobic conditions within the rising main mean that hydrogen sulphide is released, reacting with water in the sewers to create sulphuric acid which corrodes both concrete and steel.

As a result we have targeted our sewer inspection activity via remotely operated CCTV robots at these locations and completed a significant programme of rehabilitation works.

**Summary**

Whilst these operational strategies maximise use of existing maintenance budgets, it is clear from the above modelling that in the longer term scenarios we have tested there is a requirement for increasing rates of replacement to avoid increasing levels of reactive maintenance of collapsed sewers which have the potential to cause pollution incidents, and therefore we expect to request this increase at PR29 to begin increases in AMP9 2030-35.

| Asset class | | Unmitigated | | | Mitigated | | |
|---|---|---|---|---|---|---|---|
| | | 5 year | 10 year | 25 year | 5 year | 10 year | 25 year |
| **Pipelines** | 1.2 Gravity sewers | ↘ | ↓ | ↓ | ↔ | ↘ | ↓ |

## 1.3 Rising Mains

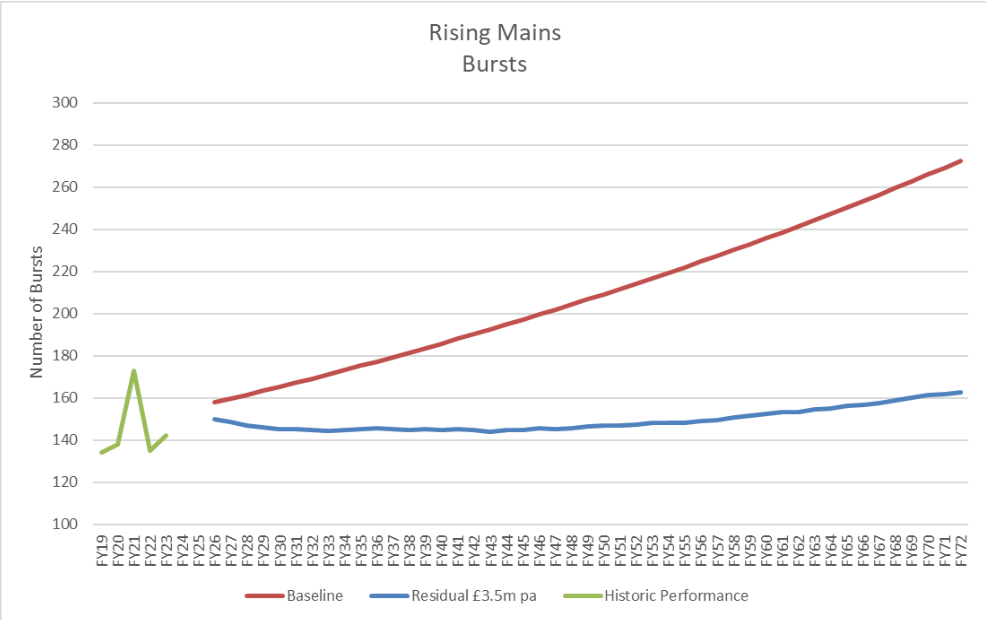
Rising mains are pumped sewers that connect parts of sewer catchments and sometimes feed through to the treatment plant, owing to their nature they can cause significant pollutions on failure as some are so large that they are impossible to replace with HGV tankers, requiring temporary overland pipework to keep the flow maintained. This asset base includes pipes at around 1,400 pumping stations that were adopted in 2016, over 800 of which we have no rising main asset records for and are working to populate these ahead of PR29. Where we have no records the pipes are excluded.

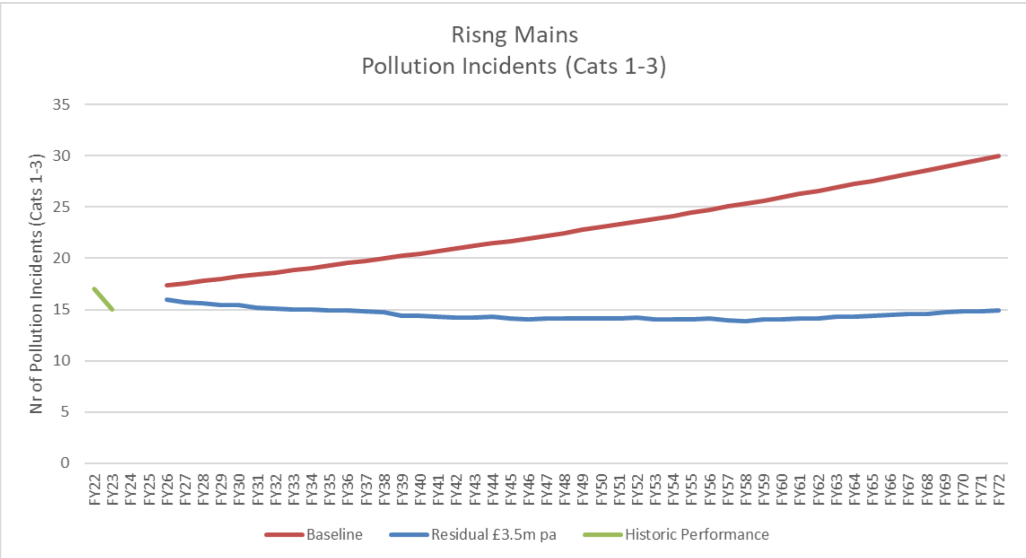
During AMP7 we have significantly increased rising main maintenance as part of our pollution incident reduction plan accompanied by investment in pump controls and flow monitoring to provide early warning of issues. Rising main repairs can involve significant temporary works to avoid pollutions during downtime for maintenance work, with individual rising main repair projects running to over £1m.

*Figure 16: Temporary overland pipe as part of rising main repair*


In AMP8 we plan to reduce expenditure compared to the elevated AMP7 levels, and have tested a spend rate of £3.5m per year in AMP8. The blue line in the graph below shows the number of residual bursts with expenditure of £3.5m per annum. As the blue line is flat over the period this indicates that there is sufficient to maintain a stable level of bursts and also a stable level of pollution incidents in AMP8 and AMP9.

The modelled numbers in the two graphs below have been indexed.




**Mitigation**

We have significantly increased monitoring of rising mains in recent years, including improved control of pumping systems to regulate pressure transients and deployment of sensors to identify rapid changes in pressure associated with rising main failure. This is an integral part of our Pollution Incident Reduction Plan (PIRP). We are also improving air valve inspection and replacement programmes and introducing trails on satellite imagery akin to leakage detection on water mains. We will continue to roll out this technology and explore new options as they become available.

**Summary**

Based on the above analysis we believe that our current levels of rising main replacement are sustainable and do not need an increase in AMP8. We will continue to review and update this position in future iterations of this document.

| Asset class | | Unmitigated | | | Mitigated | | |
|---|---|---|---|---|---|---|---|
| | | 5 year | 10 year | 25 year | 5 year | 10 year | 25 year |
| **Pipelines** | 1.3 Rising mains | ↔ | ↔ | ↔ | ↔ | ↔ | ↔ |

## 1.4 Water treatment works

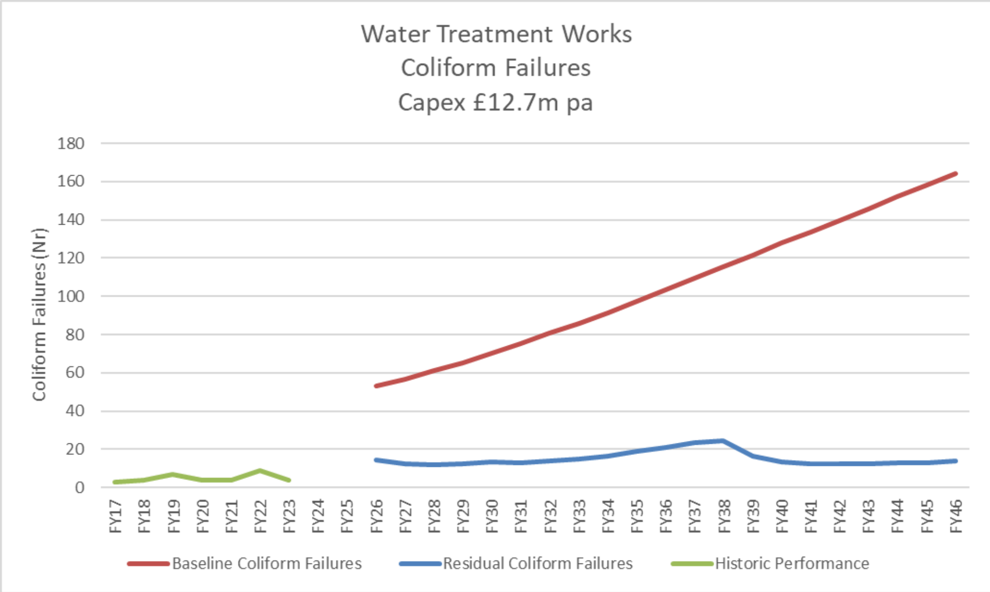
No set of mechanical and electrical assets have continuous availability, but we seek to minimise the level of unplanned outage and report that annually to Ofwat. Currently the level of unplanned outage at water treatment works (WTWs) is at 1.91% (2022-23). In our Water Resource Management Plan (WRMP) we have to make assumptions about the level of unplanned outage into the future as when equipment fails or is taken offline this reduces our WTW resilience by creating single points of failure and increases the risk of loss of supply events impacting on customers. Currently our WRMP makes the assumption that the absolute level of outage remains stable at 22 to 23 Mld lost through to 2025 but as a percentage of deployable output (DO) it increases from 1.7 to 2.6% because DO decreases due to climate change and other factors.

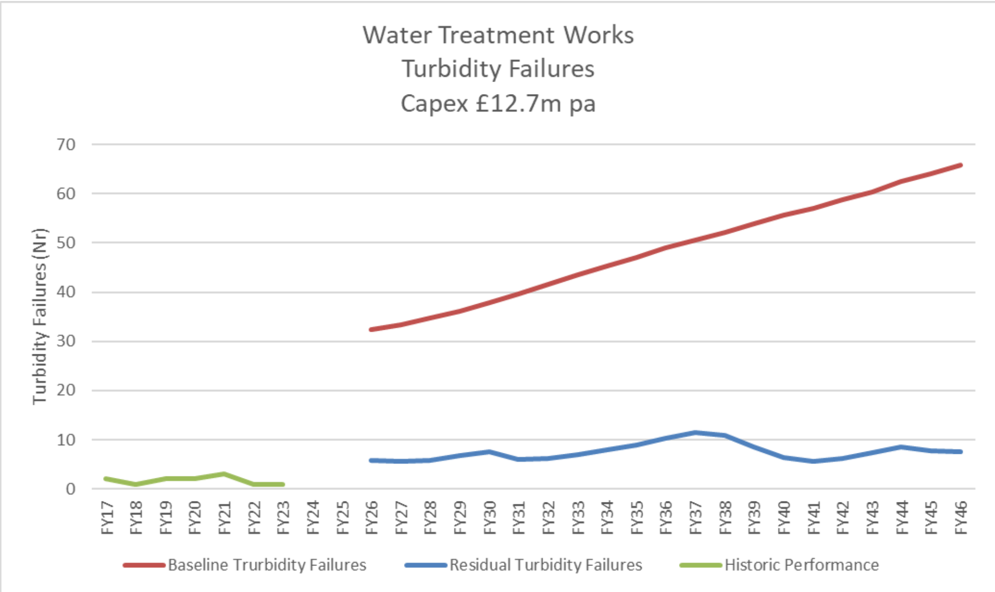
*Figure 17: Example Water Treatment Works assets*

WTW performance can be measured in terms of coliform and turbidity failures which can occur when assets fail, and treatment processes don't perform as they should.

The two graphs below show the residual number of coliform and turbidity failures achieved with expenditure of £12.7m pa. This is equivalent to the expected AMP7 spend and is the level we are proposing will also be spent in AMP8. The graphs show that performance is expected to remain stable during and beyond AMP8.

The modelled residuals compare well with the historic performance, so no indexing of model outputs has been carried out. Predictive Analytics assumes asset dependent, rule based repeat interventions which are reflected in the undulations in the residual lines.




Coliform and turbidity failures are two indicators of asset performance that contribute to the Performance Commitment ‘Compliance Risk Index’ (CRI). However they do not represent a complete analysis of all sub-measures within CRI. We have many water treatment works assets with short asset lives that were installed in previous periods for instance ultraviolet disinfection systems, nitrate removal ion exchange plants and ozone treatment systems. Our understanding of asset deterioration of these assets is still evolving.

As part of the ongoing work of the Operational Resilience Working Group (ORWG) established by Ofwat, an Integrated Monitoring Framework[12] has been set up to begin collecting data on asset health. In 2022 we provided data on unplanned maintenance on water treatment works, which showed:

- Total unplanned maintenance jobs have reduced since 2020-21 except for a slight increase for size bands W1 and W6
- Overall reduction of unplanned maintenance from 18.3% (2020-21) to 17.4% (2021-22)

[12] Ofwat-Operational-resilience-discussion-paper-April-2022-1.pdf

- The largest percentages of unplanned work are in the smaller size bands with largest size bands having the least amount of unplanned work

**Climate change analysis**

As part of our Climate Adaptation Report 2020, we noted the risk of high temperatures on our asset base. Since then we have experienced record highs with the all-time UK record set in our region during 2022, and global records broken in 2023. During the peak period many of our water treatment works assets, such as pumps and control panels, required temporary air conditioning equipment to be installed to keep them from overheating. Given the projected increases in air temperature over time we have included in our plan resilience enhancement investment for permanent measures to reduce ambient air temperature around key water treatment assets. We have considered options of ventilation, natural shading and air conditioning, with more information available in our Resilience Enhancement Case on these investments.

**Summary**

Based on the above analysis we do not propose increases in water treatment works maintenance expenditure in the short term. However, we are aware of a shortcoming of our analysis of treatment works assets which will tend to underestimate required capital maintenance. The simulations use source data from the assets captured in our corporate system, SAP. Our Asset Capture technicians are completing physical inspections of all sites to improve data quality, but have up until now found a proportion of assets not captured. Whilst we compensate for this issue in our analysis by creating 'inferred assets' to include in the simulations, inevitably this creates uncertainty until the Asset Capture site inspections are further progressed ahead of PR29.

We are also concerned about the level of confidence of the analysis in particular for civil structures on water treatment works which have no failure history to calibrate the model and have less regular, but higher cost maintenance work than mechanical assets. Many of our water treatment works buildings, steel vessels and concrete storage tanks were installed prior to privatisation and some exhibit cracking. As we finalise this document we are aware of an operational incident on a Water Treatment Works with the root cause being structural failure of steel components of filter systems. We plan to better quantify the risk of this issue in future iterations of this resilience appraisal.

For these reasons we set the 25 year long term risk to amber.

| Asset class | | Unmitigated | | | Mitigated | | |
|---|---|---|---|---|---|---|---|
| | | 5 year | 10 year | 25 year | 5 year | 10 year | 25 year |
| **Treatment** | 1.4 Water treatment works | ↔ | ↔ | ↘ | ↔ | ↔ | ↘ |

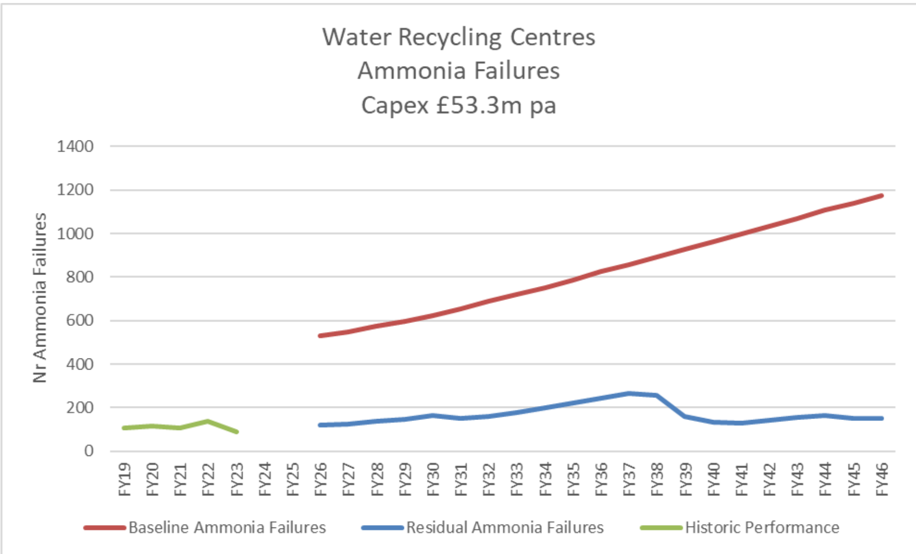
## 1.5 Water Recycling Centres

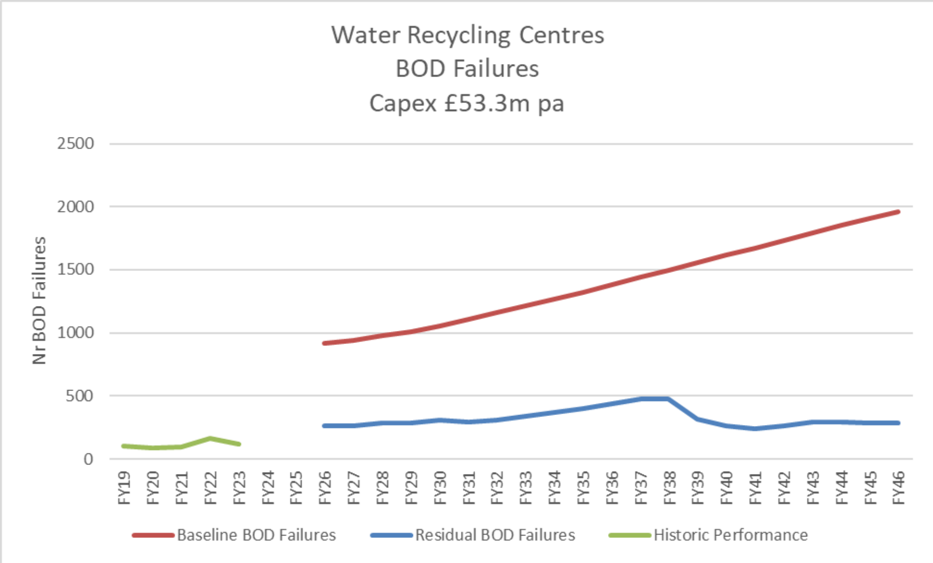
Water Recycling Centre performance can be measured in terms of ammonia, BOD and suspended solids failures which can occur when assets fail, and treatment processes don't perform as they should. Because of the tightness of permits we are asked to achieve, increasingly we are being forced to install high complexity treatment technologies with shorter asset lives on our sites, tending to increase maintenance costs. Ofwat said during the CMA that this was a choice within management control, however we are now achieving Technically Achievable Limits (TAL) determined by a collaborative UKWIR trial that selected only 2 feasible technologies able to hit these performance levels, both of which have short life high complexity assets.

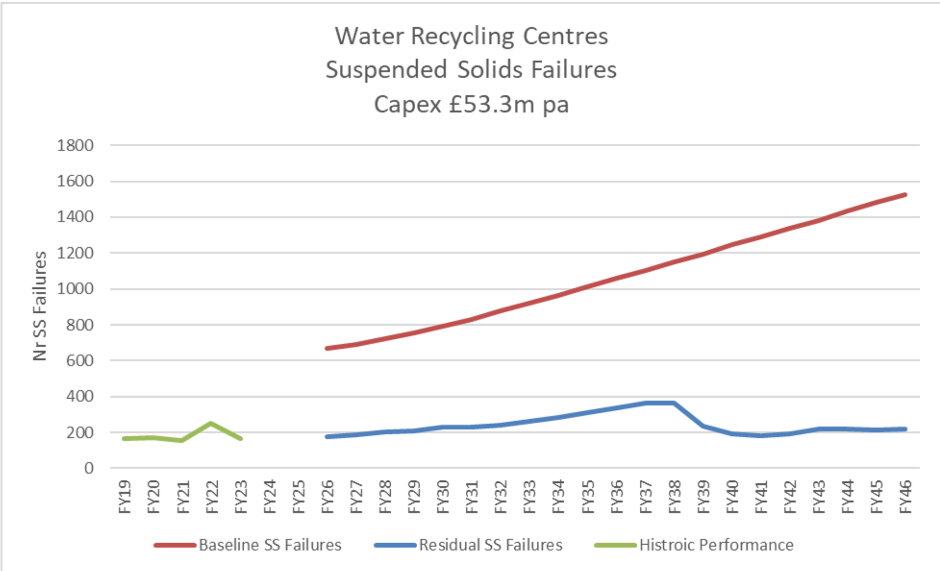
The three graphs below show the residual number of ammonia, BOD and suspended solids failures achieved with expenditure of £53.3m pa.  This is equivalent to the expected AMP7 spend and is the level we are proposing will be spent in AMP8 too. The graphs show that performance is expected to remain stable during and beyond AMP8. We have designated performance after 25 years to be amber due to the uncertainty of modelling over an extended time frame.

The modelled residuals compare well with the historic performance, so no indexing of model outputs has been carried out. Predictive Analytics assumes asset dependent, rule based repeat interventions which are reflected in the undulations in the residual lines.

Each of our Water Recycling Centres has a permit that is specific to the site, detailing the level of compliance that must be achieved for each parameter, and providing a 'Look Up Table' that details how many times a works can fail to achieve the required level before the works is deemed to be a failing works, leading to a reduction in the Performance Commitment Treatment Works Compliance. Therefore whilst these simulations and projections of performance are helpful in determining required levels of asset maintenance, they cannot be directly compared with predictions of Treatment Works Compliance. In the future we plan to more closely align our parameter specific forecasts with Performance Commitment predictions.






Whilst these parameters provide a guide to water recycling centre performance in the long term, they are not the only measures of performance. For example sludge thickening assets on water recycling centres which are short life assets may not directly contribute to failing samples, but can impact sludge transport costs. Equally some assets when they fail will lead to flow compliance issues such as premature storm overflows. We currently deal with these issues outside of modelled asset maintenance, using manually generated investments within base costs, and will continue to monitor these issues and include further information in future iterations of this appraisal.

As part of the ongoing work of the Operational Resilience Working Group (ORWG) established by Ofwat, an Integrated Monitoring Framework[13] has been set up to begin collecting data on asset health. In 2022 we provided data on unplanned maintenance on Water Recycling Centres which showed that:

- Total unplanned maintenance jobs have reduced across all size bands except above band 5 since 2020-21

[13] Ofwat-Operational-resilience-discussion-paper-April-2022-1.pdf

- Overall reduction of unplanned maintenance from 66.3% (2020-21) to 58.2% (2021-22)
- The introduction of dedicated planned maintenance teams ensure that planned maintenance is protected
- A change to the maintenance strategy has been introduced based on asset history and performance

**Summary**

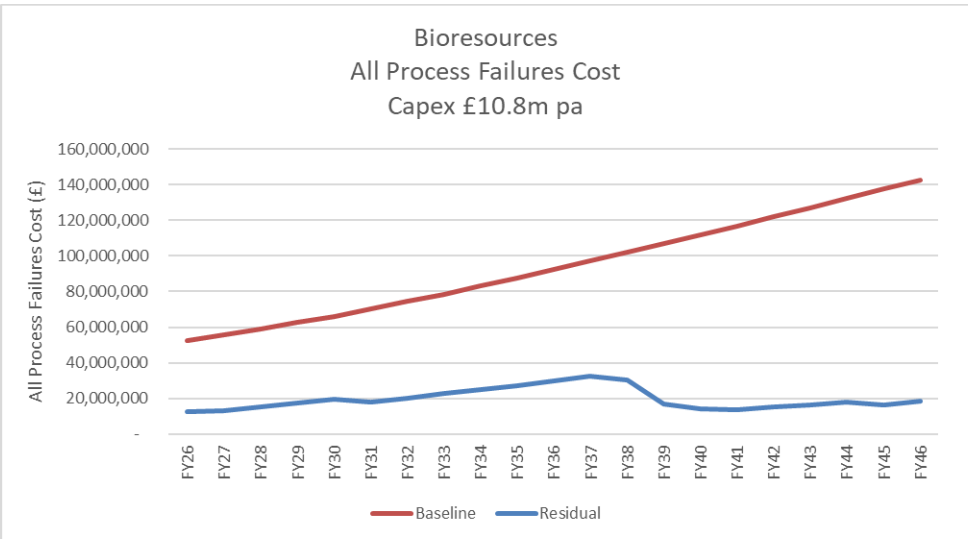
Based on the above analysis we do not propose increases in water recycling treatment works maintenance expenditure in the short term. However, as explained in relation to water treatment works, we are concerned about the level of confidence of the analysis in particular for civil structures which have less regular, but higher cost maintenance work than mechanical assets. For this reason we set the long term risk to amber, meaning that we currently believe beyond 2030 we will need to increase maintenance expenditure in this area.

| Asset class | | Unmitigated | | | Mitigated | | |
|---|---|---|---|---|---|---|---|
| | | 5 year | 10 year | 25 year | 5 year | 10 year | 25 year |
| **Treatment** | 1.5 Water recycling centres | ↔ | ↔ | ↘ | ↔ | ↔ | ↘ |

## 1.6 Bioresources

For investment planning of bioresources we use a monetised measure called All Process Failures Cost. The graph below shows the residual achieved with expenditure of £10.8m pa. This is equivalent to the expected AMP7 spend and is the level we are proposing will also be spent in AMP8. The graphs show that performance is expected to remain stable during and beyond AMP8. We have designated performance after 25 years to be amber due to the uncertainty of modelling over an extended time frame.

Predictive Analytics assumes asset dependent, rule based repeat interventions which are reflected in the undulations in the residual lines.




**Mitigation**

We currently observe an asset availability uptime on our Sludge Treatment Centres typically between 80-85%. Our Bioresources strategy and enhancement case target a stetch of 90% uptime, but plans for capacity need using 85%. That aligns to other manufacturing / factory type operations that typically operate in the 80-90% range. Recently Ofwat have requested a Bioresources asset health assessment, requiring a full asset condition, performance and asset management assessment across all fixed assets in the price control. We will complete this data later this year and use it where possible to improve asset records, target asset maintenance and improve performance.

**Summary**

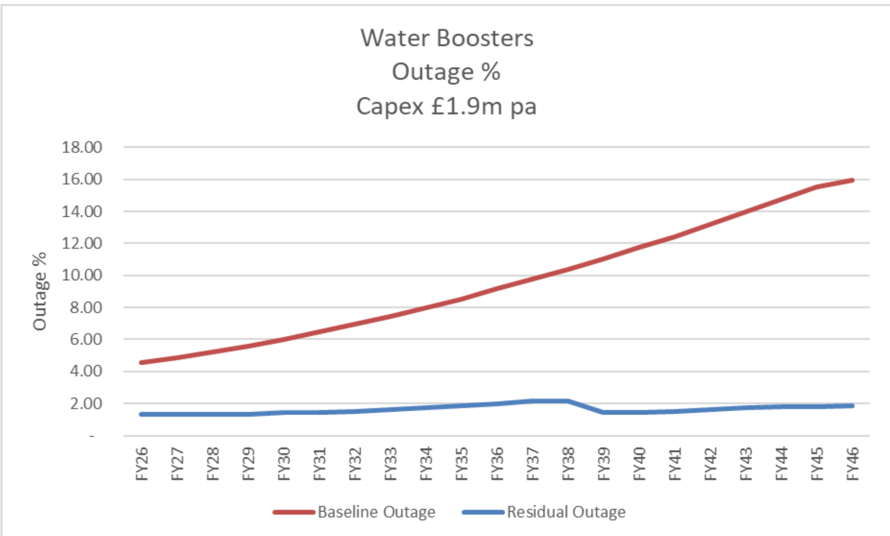
Based on the analysis above we do not request additional maintenance for bioresources assets at this time. However, it should be noted that bioresources assets include unmodelled assets such as HGVs and therefore bioresources capital maintenance may potentially need to change in future for reasons beyond this analysis. We will continue to review this in future.

| Asset class | | Unmitigated | | | Mitigated | | |
|---|---|---|---|---|---|---|---|
| | | 5 year | 10 year | 25 year | 5 year | 10 year | 25 year |
| **Treatment** | 1.6 Bioresources | ↔ | ↔ | ↘ | ↔ | ↔ | ↘ |

## 1.7 Water Boosters

Water Booster performance is measured in terms of unplanned interruptions to supply which can occur when booster assets fail. To make the numbers more meaningful, the Unplanned Interruptions Total Property Seconds (>3 hrs) figures output by Predictive Analytics have been converted into an approximation of outage percentage by dividing by the total number of property seconds in a year across our region.

The graph below shows the residual outage percentage achieved with expenditure of £1.9m pa. This is equivalent to the expected AMP7 spend and is the level we are proposing will be spent in AMP8 too. The graph shows that performance is expected to remain stable during and beyond AMP8. Predictive Analytics assumes asset dependent, rule based repeat interventions which are reflected in the undulations in the residual lines.



The operation of water booster pumping stations is critical for the protection of the network itself. As explained above we have invested heavily in pressure management and mitigation of transient pressures in our network, so it's vital that these assets continue to operate efficiently.

**Summary**

Based on the above analysis we do not request increases in expenditure for this asset type.

| Asset class | | Unmitigated | | | Mitigated | | |
|---|---|---|---|---|---|---|---|
| | | 5 year | 10 year | 25 year | 5 year | 10 year | 25 year |
| **Pumping** | 1.7 Boosters | ↔ | ↔ | ↔ | ↔ | ↔ | ↔ |

## 1.8 Sewage Pumping Stations

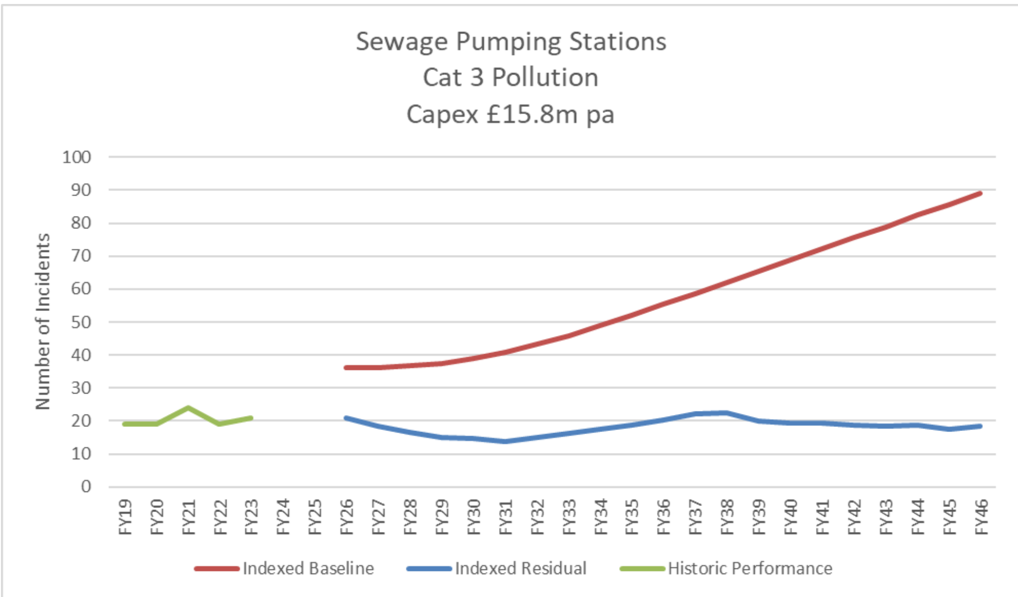
Sewage Pumping Station performance can be measured in terms of the pollution and flooding they cause when assets within them fail.

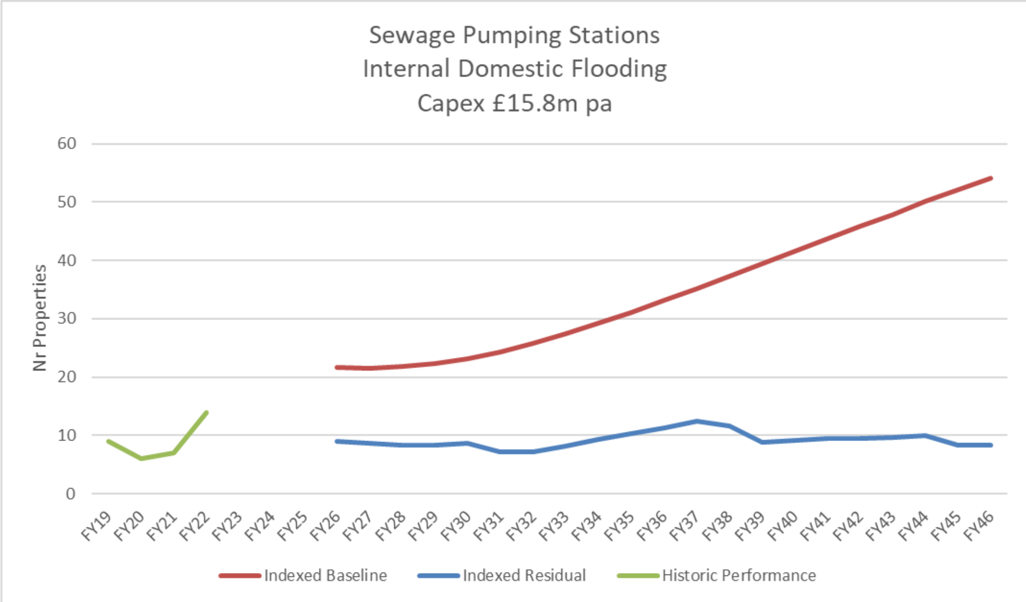
The two graphs below show the residual numbers of Category 3 pollution and internal domestic flooding incidents achieved with expenditure of £15.8m pa.  This is equivalent to the expected AMP7 spend and is the level we are proposing will be spent in AMP8 too. The graphs show that performance is expected to remain stable during and beyond AMP8.

The modelled residuals have been indexed to align with historic performance and allow comparison with it. Predictive Analytics assumes asset dependent, rule based repeat interventions which are reflected in the undulations in the residual lines.

Pollutions from pumping stations can be caused by multiple factors other than asset failure, such as power failure and blockages from unflushables. We explain more about our approach to power failure risk in section 4 of this document.

The modelled numbers in the two graphs below have been indexed.






As part of the ongoing work of the Operational Resilience Working Group (ORWG) established by Ofwat with the aim of "forming a more holistic and complete view of asset health and wider operational resilience in the sector", an Integrated Monitoring Framework[14] has been set up to begin collecting data on asset health. In 2022 we provided data on equipment failure on sewage pumping stations, which showed:

- Pumping station equipment failures have reduced by 12% from 2020-21 to 2021-22.
- Vacuum Sewerage Systems and chemical dosing failures have increased by 8% and 23% respectively from 2020-21 to 2021-22.
- There is an overall reduction in equipment failures since 2020-21.

**Mitigation**

We want to reduce pollutions to zero and have set out our ambition for 2050 of zero escapes from our network. Whilst this analysis shows stable performance achieved by base expenditure, we believe that is unacceptable and seek further strategies to drive down levels of pollution due to asset failure. In the past we have used frequency based maintenance schedules for the proactive maintenance of our pumping stations. In recent years we have invested in automation of the maintenance of our pumping stations, meaning that the assets are now continually monitored via machine learning, calling for proactive maintenance when performance drops rather than at a point in time. This in part has resulted in the reduction in equipment failures seen above. In addition we are investing in increased monitoring of emergency overflows from pumping stations to improve response time and reduce severity of pollutions.

**Summary**

Based on the above analysis we do not request increased maintenance of this asset type in the short term to 2030.

[14] Ofwat-Operational-resilience-discussion-paper-April-2022-1.pdf

| Asset class | | Unmitigated | | | Mitigated | | |
|---|---|---|---|---|---|---|---|
| | | 5 year | 10 year | 25 year | 5 year | 10 year | 25 year |
| **Pumping** | 1.8 Sewage pumping stations | ↔ | ↔ | ↔ | ↔ | ↔ | ↔ |

## 1.9 Storage points

During the first three years of AMP7 there have been 36 coliform failures at storage points where the root cause is likely to be ingress of rainwater into the storage point via cracks in hatches or roofs.

The expenditure provided for storage points in AMP7 is only around half the level required to carry out basic reactive maintenance. The shortfall has been made up by reallocation of budget from other areas of the Treated Water Distribution portfolio. In AMP6 the shortfall was made up by reinvestment of outperformance in other programme areas. However, no proactive refurbishment or replacement has been funded for at least three AMP periods, including AMP7, leading to a deterioration in water storage point asset condition which will lead to significant increased costs in this portfolio area in the coming years.

The inadequate maintenance in AMP7 and previous AMPs has led to a predominantly "repair" rather than "replace" strategy which leads to a higher storage point risk profile. For example, in most cases we can only afford to repair tank roof membranes where they are leaking rather than replacing the complete membrane because it is past its useful life, and we can only afford to repair sections of joints where there is ingress rather than replacing all of them that are of a similar age and condition. We have not been able to fund work to solve the increasing problem of spalling concrete on water towers which is a structural, health and safety (objects falling from height), and reputational issue. We have also not been able to formulate a proactive storage point replacement strategy. The forward-looking risk-based analysis described below supports the need for increased expenditure.

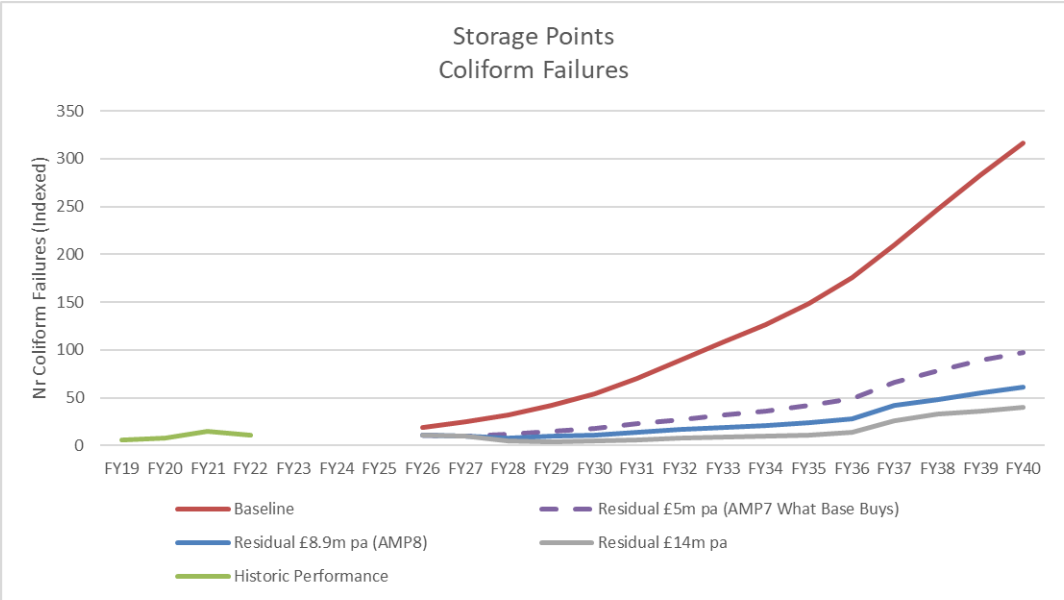
*Figure 18: Example water storage point*

Storage point performance is measured in terms of coliform failures. These occur when the structural integrity of a storage point is compromised and contaminated water from outside the structure finds its way inside.

The purple dotted line in the graph below shows the residual number of coliform failures that would occur if expenditure in AMP8 continued at the AMP7 level of £5m per annum. This level of expenditure would cause an increase in coliform failures during AMP8. To keep failures stable during AMP8 expenditure of £8.9m per annum is needed (blue line). This is the proposed level of spend for

AMP8, however, this is insufficient beyond AMP8 when failures would start to rise. Expenditure of £14m per annum (grey line) starting in AMP8, would be needed to keep coliform failures stable in AMP8 and AMP9.

The modelled numbers in the graph below have been indexed.




**Summary**

Based on the analysis above we have increased the level of expenditure for storage points within our base plan for 2025-2030, by reallocating from other areas. The increased level of expenditure is below Ofwat's threshold for Cost Adjustment Claims. We will seek to secure further increased allowances from AMP9 onwards via PR29, potentially reaching a level of around £14m per year.

| Asset class | | Unmitigated | | | Mitigated | | |
|---|---|---|---|---|---|---|---|
| | | 5 year | 10 year | 25 year | 5 year | 10 year | 25 year |
| **Storage** | 1.9 Storage points | ↘ | ↓ | ↓ | ↔ | ↘ | ↓ |

## 2. Forecast Risk of dam failure

We have 43 reservoirs registered under the Reservoir Act, 36 of which are designated as high risk of inundation of urban areas if breached. We comply with the Reservoir Act 1975 through a three tiered system of monitoring via:

a) weekly/monthly checks by operational staff documented via SAP which generates a weekly/monthly checklist for each reservoir
b) planned inspections from our Supervising Engineer at least six monthly to each reservoir followed by Annual Reports being issued to the EA and
c) planned section 10 (10 yearly) inspections by independent Inspecting Engineers chosen from framework consultants.

Compliance with actions required under the reservoir act is monitored at a quarterly meeting of managers and an annual report is produced for directors. Issues raised at the six monthly inspections are tracked via the raising of actions for the supply manager on the 'Action Management System' and statistics from these are reported in the annual report. Statutory actions raised by the Inspecting Engineers are reviewed at quarterly meetings and reported in the annual report. Monitoring of weekly/monthly inspections is reviewed by the Supervising Engineer via a Power BI report and compliance is reported by the Supervising Engineer to the EA and in the annual report to the directors. Audits of compliance with the Reservoir Act quality procedure are carried out internally and externally every six months.

Our PR24 plan includes investment to carry out this inspection work at an expanded list of sites since the Reservoir Act has been amended to include smaller volume assets. The plan also includes base maintenance levels. Our reservoir assets are in good condition as any issues identified are rectified in a timely manner. We do not foresee any major issues with them.

## 3. Forecast Risk of supply chain failure

We assess the criticality of our suppliers through our Business Impact Analysis process which links the services we deliver to the suppliers supporting them. We have also carried out a further assessment into the criticality of our chemicals based on a range of factors including population supplied by the assets using them and impact to the water/water recycling treatment process. This informs our sourcing strategies and the resilience options required at each level of criticality including sourcing multiple suppliers, pre-identification and testing of alternative chemicals, and documenting transportation needs if redistributing stocks between our assets during shortages.

Once contracts are let, we monitor the financial health of our critical suppliers, and if there is a change in their financial status further investigations are carried out. Any concerns or issues identified are then addressed and outcomes reported to the wider business on a monthly basis.

We have also carried out a supply chain mapping exercise to understand the dependencies for our chemical suppliers, their subcontractors, where their products are used and stored, the raw materials and transportation routes used, including ports if sourced from abroad. This enables us to horizon scan more effectively and quickly understand when geopolitical risks have the potential to impact our operations. Further work is also being carried out to link our wider supply chain to the commodities they are reliant on to further enhance our horizon scanning and supply chain risk management processes.

Our incident management framework includes plans to respond to chemical supply chain disruptions. Our director of Strategic Delivery & Commercial Assurance chairs an industry supply chain resilience committee. We work collaboratively with other water companies to respond to issues with shared suppliers and there is a well-established process in place for allocating deliveries based on impact. We also work with our chemical suppliers and recently carried out a resilience exercise with them focusing on the response to cyber-attacks and power outages. This helped raise awareness with our suppliers of our needs and expectations and informed our own planning and notification processes.

We do not include additional investment in our plan at this stage for supply chain risk, but will continue to work collaboratively with stakeholders to mitigate this risk in the future.

## 4. Forecast risk of power supply outage to sites

We plan for a range of power supply outages from single sites to regional and national power outages. Our risk assessments are informed by the National Security Risk Assessment (NSRA) produced by the Cabinet Office, which takes into account historical precedent, expert judgement and statistical models or forecasts to produce a risk assessment which is then contextualised for relevance to our area by Local Resilience Forums across the region.

The NSRA contains several risks which could result in the loss of power including both malicious and non-malicious events, such as storms, failure of regional and national electricity transmission systems, and conventional or cyber-attacks on electricity infrastructure.

Using these planning assumptions, we have carried out scenario planning for the failure of power at a national and regional scale to understand the impacts of power outages on our water and water recycling treatment assets, in conjunction with WaterUK and Defra through Project Yarrow, a cross-sector review of power resilience for the UK.

We have a Loss of Power plan covering the business response to regional and national power outages including both immediate power outages and planned rota disconnections and have worked with the Distribution Network Operators to understand the impacts of both.

Through our work with Local Resilience Forums, we have also assessed the wider societal impact of power outages and the interdependencies between the water industry and other critical national infrastructure. Defra recognises the wider societal impact that loss of water supplies would have in such scenarios and as such have commented that investment cases for PR24 to improve power resilience would be favourably considered.

All Water Treatment Works are protected by backup generators and our minimum asset standard mandates 10 days fuel storage on sites where generators are installed. Critical Water Treatment Works sites have asset resilience plans in place identifying contingencies should power supplies fail, including backup generators and rezoning options. However, only 27% of pumping stations are supported by backup generator, and initial assessments indicate this could result in the loss of supply or low pressure to 600,000 properties during a national power outage.

Water Recycling Centres and Sludge Treatment Centres have been assessed using a range of factors to identify whether they are classed as high, medium or low criticality which would determine our response during a power outage scenario. All pumping stations have been ranked based on past performance commitment failures (pollution, flooding etc) and high opex site visits. This ranking has been used to identify pumping stations where capital solutions could be installed to minimise the impact of power outages including brownouts at sites, such as generator sockets, back up floats, phase failure relay, brown out timers, air locking prevention, generator auto starts and auto pump changeovers. When storms are forecast we often deploy mobile generators to these sites in preparation.

At PR19 and through the AMMA, Ofwat have encouraged companies to review the resilience of their assets as part of a 'system of systems' understanding the linkages with other utilities. Since PR19 we have taken part in a national pilot scale project called Climate Resilience Demonstrator (CReDo). This is a collaboration with UK Power Networks and BT, analysing the effects of flooding on all three asset bases simultaneously in a trial area. The model uses connectivity and dependencies between assets to identify critical vulnerabilities to flood risk, with phase 2 looking at high temperature risk - What is CReDo? - DT Hub Community (digitaltwinhub.co.uk)

As part of the project we commissioned this short film to illustrate the impact that climate related asset failures can have on communities and we urge the reader to watch to bring the issue to life: Tomorrow Today - 2021 Short Film from NDTp's Climate Resilience Demonstrator (CReDo) project – Full - https://youtu.be/iluoK6iKrxE

We do not include any additional funding in our plan for power resilience at this time, but will continue to improve our understanding of the risk, expanding CReDo to phase 2.

## 5. Forecast risk of flooding from rivers, coastline

The Anglian region has a high proportion of flat and low-lying areas, including The Fens in Cambridgeshire and the Norfolk Broads. A quarter of our region lies below sea level which means we are acutely aware of the risk of flooding to our assets, and the knock-on impact this could have on the service we provide to customers and the environment.

**Understanding the risk of flooding to our assets**

Building on our experience of assessing flood risk at PR14 and PR19, we have recently worked with Ambiental and Royal HaskoningDHV to undertake the latest and most detailed flood risk assessment of our assets ever undertaken.

This work involved modelling and mapping to screen all water and water recycling above ground assets to establish a long list of sites at risk. Pluvial, fluvial, coastal and groundwater risks were all assessed. We used a range of scenarios to assess the risk, including four climate change scenarios (including RCP 2.6 and RCP 8.5 from UKCP18 which equate to 2° and 4° temperature rises), four epochs (looking out to 2025, 2030, 2035 and 2050), and six storm return periods (1:30, 1:75; 1:100, 1:250, 1:500 and 1:1,000).

We then undertook a detailed site assessment process to generate a short list of sites with a significant risk to service from flooding. This included a detailed desk-top analysis, asset owner verification and site visits to assess the probability and consequence of flooding.

**Our findings**

With more detail about the flood risk to our assets than we've ever had before, we are now able to assess in greater depth what the risk (the combination of probability and consequence of failure) is of asset failure. We are also better able to consider both the impacts of temporal scale and climate change on the risk to our assets, having received results for four separate epochs, and four climate change scenarios. Combined with the six storm return periods for three separate types of flood risk, and data for over 7,000 assets, this work has provided us with over 2 million flood depth data points.

From this data, we can see that for a 1:100 year flood event in the present day, 29% of our sites are at risk from at least one source of flooding. This drops to 21% when flooding over 200mm is considered. This breaks down to 256 assets at risk from only fluvial flooding, 1,072 assets at risk of just surface water flooding, and 716 assets at risk of only coastal flooding. However, many assets are at risk from multiple sources of flooding. For example, 123 assets are at risk from all sources of flooding, and 1,166 assets are at risk from fluvial and pluvial flooding.

The results clearly show the impact of climate change looking forward to 2050. Using a 4$^{o}$ temperature rise some interesting results are found. Most notably, fluvial flood risk drops from 256 assets to 200 assets, whilst pluvial flooding increases from 1,072 assets to 1,212 assets at risk. The likely cause of this, according to our consultants, is that river flows will reduce across the East of England due to climate change, so baseflows will be lower, whilst more intense summer storms will increase the risk of surface water flooding.

Whilst we have not considered the 'positive' impacts of climate change previously, it is clear that this data allows us to take a more nuanced view of our risk, enabling us to make informed decisions about the risk of flooding, and take an adaptive approach to investment where required.

**Next steps**

Investment to protect our assets from flooding is only proposed where it is necessary to supplement other measures that we already have in place to maintain service to our customers and protect the environment. We use the Cabinet Office's infrastructure resilience components to identify the best possible approach to managing risk, with resistance, such as flood walls, being just one solution we could use. Alternative approaches include the development of flood emergency response plans for our operatives to use when flood warnings are released by the Environment Agency.

We also have a dedicated East Coast Flood Plan which draws on the learning we have gained from past flooding events in 2007, 2013 and 2017. An east coast tidal surge is the biggest single risk to our asset base, as the risk of flooding occurs over a 12 hour period, so it is essential that we focus on this to maintain service.

**Cabinet Office Infrastructure Resilience Components**

**Resistance**
Measures include permanent flood barriers, such as flood walls around the perimeter of the site, flood walls around individual assets, flood doors, waterproofing buildings and air vent covers. We also have access to 500m of demountable flood barriers, which can be used at sites without permanent flood resilience measures.

**Reliability**
Measures included raising electrical panels and ensuring communications and telemetry are maintained during an incident.

**Redundancy**
The ability to rezone water supplies to ensure no loss of service to customers.

**Response and recovery**
High-risk sites have Flood Emergency Response Plans, which detail the actions to be taken by staff on site including the critical assets to protect and safe access routes. During incidents we have the ability both to provide potable water and to remove foul water using tankers

We include investment in our plan to address increased risk of flooding, with further details available in the Reducing Flooding Risk for Properties Enhancement Case, as well as the Resilience Enhancement Case for our own assets.

## 6. Forecast risk of deliberate attack, physical or cyber

***Physical***

The physical security of our assets is vital to the continuation of supply and treatment processes to avoid a disruption of service through incidents relating to theft and vandalism, as well as providing protection from terrorism. We also have a requirement to be compliant with the requirements under the Security and Emergency Measures Direction (SEMD 2022), the Protective Security Guidance (PSG) and Water UK Security & Electronic Standards (WUKSS).

PSG and the associated Water UK Security Standards set the Water Industry requirements for physical security and are the basis for investment to ensure our sites meet the level of physical protection detailed in those guiding documents.

We risk assess and categorise sites based on criticality to determine the level of security required. Physical security protection must continue to be maintained to this level. Any new investment which relates to SEMD, will be assessed against the PSG and Water UK Security Standards to ensure adequate standards and maintenance plans are in place using appropriate frameworks (National Protective Security Authority (NPSA) approved products where appropriate). Any deviations will be raised and recorded on the Compliance Assessment Form and the Delivery Execution Plan signed off by the Security Manager or Appointed Person.

As operators of Critical National Infrastructure (CNI) we ensure that sites are protected across all elements of security (physical, personnel, cyber, data and protection) through response plans and procedures, maintenance, exercising, audits and risk assessments.

The Physical Security team lead the liaison between Defra, DWI, Water UK, Counter Terrorism Security Advisors and NPSA with support from the other security disciplines. The physical security team inform the business of current threat levels and adapt any physical security requirements (where necessary) to ensure that assets and personnel continue to work in a safe secure environment. Governance is maintained through the Resilience Steering Group chaired by the Chief Executive.

Threats to our operational and office assets, and buildings are reviewed regularly, and any breaches such as fuel theft or vandalism are investigated, reported to Police where appropriate, and reviewed by the Security Manager to risk assess the security arrangements. This may include the provision of temporary security or monitoring until such time that the risk is lowered. With addition of further advice on enhanced security where appropriate.

Types of physical protection and technology systems across our estate are reviewed periodically or where 'end of life notification of products' is informed, to ensure they are the best method to protect sites based on risk and innovative solutions available. The Physical security team work closely with the Framework contractors supporting the maintenance and servicing of our security across the region.

We include investment in our plan to address physical security risks, with further details available in the Security Enhancement Case.

***Cyber***

We identify in excess of 30k daily connection attempts that are blocked by our Secure Operational Technology Internet Firewalls. It is not possible for us to determine what proportion of these dropped connections are specifically targeted at our industrial service and we do not routinely experience Cyber Security incidents as a result of this activity. Where security incidents occur, they are reported in accordance with Network & Information Systems regulatory guidelines.

The National Centre of Cyber Security (NCSC) advise us that the threat level to the water sector is low which implies that Advanced Persistent Threats (APTs) currently have a low level of motivation to target us. Threat levels can change and so we operate a robust risk management process which enables us to routinely assess and drive down residual risk. Our security partner operates our Security Operations Centre which includes a Threat Intelligence capability which keeps us up to date with all the latest vulnerabilities, advanced threat groups and targeted attacks.

Cyber decision making is driven jointly between Cyber and Business SMEs and links into routine risk management forums and the Resilience Steering Group which is chaired by our CEO Peter Simpson.

We include investment in our plan to address cyber security risks, with further details available in the Security Enhancement Case.

## 7. Forecast risk of long-term outage of water treatment works

Our resilience programme includes work to reduce the percentage of the population served by a single water treatment works. This protects customers from a wide range of hazards that could lead to a long-term outage of water treatment works.

The strategy began with large projects to reinforce the resilience of the areas fed from Wing Water Treatment Works and from the treatment works in the Norwich area. Grafham Water Treatment Works is our largest works supplying over 800,000 people. In 2020 the Grafham Resilience Scheme was completed which was designed to supply customers in the event of a major incident at Grafham.

It has been a long-term strategy with the aim of reducing the percentage of the population served by a single supply to zero. From a baseline of 27.5% in 2014, during AMP7 we are targeting a reduction in the percentage from 24.1% in 2020 to 14.1% per cent in 2025. Whilst we will no longer have a performance commitment in AMP8, we will continue to invest in connecting rural communities with a single source of supply in particular taking opportunities to connect them to our new strategic interconnectors during the construction of these major transfers across our region. Our PR24 plan includes investment for this reason.

Fire risk is just one of the areas of risk that is closely managed, and this is achieved through the Fire Risk Steering Group that is chaired by the Director of Water Services. This group meets regularly to monitor and advise on the risk of fire across all the company's assets as identified through site risk assessments, inspections and audits.

Investments required to reduce identified fire risks are prioritised against other needs within the company unless they are smaller scale alterations or operational changes in which case they are managed by the operational teams.

These measures reduce the risk of outages due to fire but if such a loss was to occur through fire or any other large-scale incident the impacts are mitigated by previous resilience development programmes above to ensure communities have more than one supply available.

We include investment in our plan to address single source of supply issues, with further details available in the Resilience Enhancement Case.

## 8. Forecast risk of raw water contamination

The risk of contamination to raw surface and groundwater sources is assessed once per AMP (as a minimum) at every surface and groundwater source through our Surface Water Risk Assessment (SWRA) and Catchment Risk Assessment for Groundwater Sources (CRAGS) processes.

The CRAGS process follows the source-pathway-receptor model and comprises a combined desk and site-based audit. The site-based audit incorporates a borehole headworks condition assessment to ensure there is a hygienic seal to the borehole. Non-conformities are raised on our action management system (AMS) for remediation through our groundwater budget, where budget is available for a predefined number of outputs each year of the AMP.

The SWRA process is a desk based two-stage process looking at the assessment of risk using point and diffuse contamination information from the catchment and validating the risk against water quality data. As part of the first process we consider:

- The point sources within the catchment which could give rise to higher concentrations of parameters/pollutants e.g. landfill sites, transport networks, discharge consents.
- Diffuse catchment data on land use and hydrological conditions including travel time to intake.
- Pollution incidents and events.

The second process looks at the output from stage one and compares it with raw water quality sampling data.

Risk scores for both CRAGS and SWRA processes are generated for water quality parameters using a risk scoring methodology and are subsequently validated on an annual basis using raw water sample data collected through our regulatory sampling programme. Validated scores are entered into our Water Quality Risk Portal, enabling source-to-tap tracking of water quality risks and fulfilling our obligations under Regulation 27 and 28 of the Water Supply (Water Quality) Regulations 2016.

In addition to the once-per-AMP assessment, emerging groundwater and surface water contamination risks are identified and monitored by way of our Catchment Surveillance process. Catchment surveillance checks are completed for all surface and groundwater sources as part of routine site visits to ensure emerging risks in the vicinity of raw water abstraction points are identified as soon as possible. This enables timely mitigation and minimises the risk of a deterioration in raw water quality. Our dedicated Catchment team provide support to our Water Resources team in liaising with catchment stakeholders where emerging issues are identified. An app-based reporting system for catchment surveillance was commissioned during AMP7 and has been rolled out across the business.

Our Catchment Team lead in the delivery of Catchment Management initiatives, working with agricultural stakeholders across our groundwater and surface water catchments to manage and mitigate point and diffuse source contamination risks from a range of agricultural pollutants; specifically, nutrients and plant protection products – for example, herbicides. Initiatives include grant funding schemes for contamination mitigation measures, cover crops and field trials, technical training events, and focussed site visits to improve awareness of raw water source contamination risks in vulnerable catchments.  The team also provide support to Water Resources and Water Quality colleagues in response to any deterioration in raw water quality linked to agriculture.

The CRAGS, SWRA and Catchment Surveillance processes are documented in our Policies and Standards for Water Supply Hygiene (POSWSH) procedures, which are reviewed every three years.

A number of groundwater sources have previously been or are currently impacted by historic contamination incidents.  These non-operational assets are reviewed on an annual basis and recorded in our annual Asset Performance Report, including commentary on the reason or reasons for the asset being non-operational.

We have dedicated trends and forecasts for nitrate contamination of aquifers in vulnerable groundwater catchments in order to forecast future concentrations and enable proactive strategic planning for future investment decisions, reducing the risk of outages relating to deteriorating water quality.  We also monitor sulphate concentration in our Hartlepool area - comprising ten operational groundwater sources – in conjunction with the Environment Agency and Coal Authority.  This is related to historic mining contamination.

In order to reduce the risk of asset condition-related quality issues with raw groundwater sources we conduct a programme of asset condition monitoring and asset maintenance activities each AMP.

We work closely with the Environment Agency and industry groups in relation to contamination incidents in groundwater and surface water catchments, and also with regard to emerging contaminants of concern, such as PFAS.

As a result of the above process our plan includes enhancement of several borehole headworks found to be vulnerable to ingress during flood events, with further details available in the Resilience Enhancement Case.

## Economic tests

To ensure a rounded assessment, we have looked at a range of economic and financial tests to compare with the detailed engineering analysis described above:

### Broad equivalence

During the CMA process Ofwat provided evidence that companies were not in a 'maintenance trough' citing increases in £m spent on capital maintenance in real terms since privatisation. However, these increases were not indexed against growth in the asset base. For the first four AMPs after privatisation, Ofwat used the broad equivalence test as a measure of sustainability of asset maintenance. The test compares the spend on capital maintenance with Regulatory Capital Value (RCV) run-off, on the basis that RCV run-off is strongly linked to asset depreciation and therefore capital maintenance should be broadly equivalent to depreciation. Disadvantages of this analysis include the fact that not all assets are captured in RCV and therefore it will tend to underestimate required maintenance, as well as the assumption that all capital maintenance is spent on physical assets as opposed to, for example, IT systems.

The table below shows our capital maintenance spend per AMP over time (all figures normalised to 17/18 price time basis, and including maintenance expensed since 2016 IFRS accounting rules):

*Table 5: capital maintenance by AMP.*

| AMP | Water £m | Water Recycling £m | Wholesale £m |
|---|---|---|---|
| 3 | 493 | 744 | **1,236** |
| 4 | 640 | 954 | **1,594** |
| 5 | 584 | 787 | **1,371** |
| 6 | 576 | 765 | **1,341** |
| 7 (Plan) | 523 | 731 | **1,254** |

We have updated the measure with data to 2021. The results showed that across the industry, Capital Maintenance per property is generally lower for Water Recycling than for Water. On a per property basis, our Water current expenditure is the lowest in the industry. Our highest normalised figure for Water since 2000 is only marginally above the lowest figure for Welsh Water.

When normalised on the size of our asset base (as measured by RCV), our total expenditure has been below the industry average in both services for the last four AMPs (two decades), with wholesale capital maintenance above the run-off rate for only three out of the last 20 years.

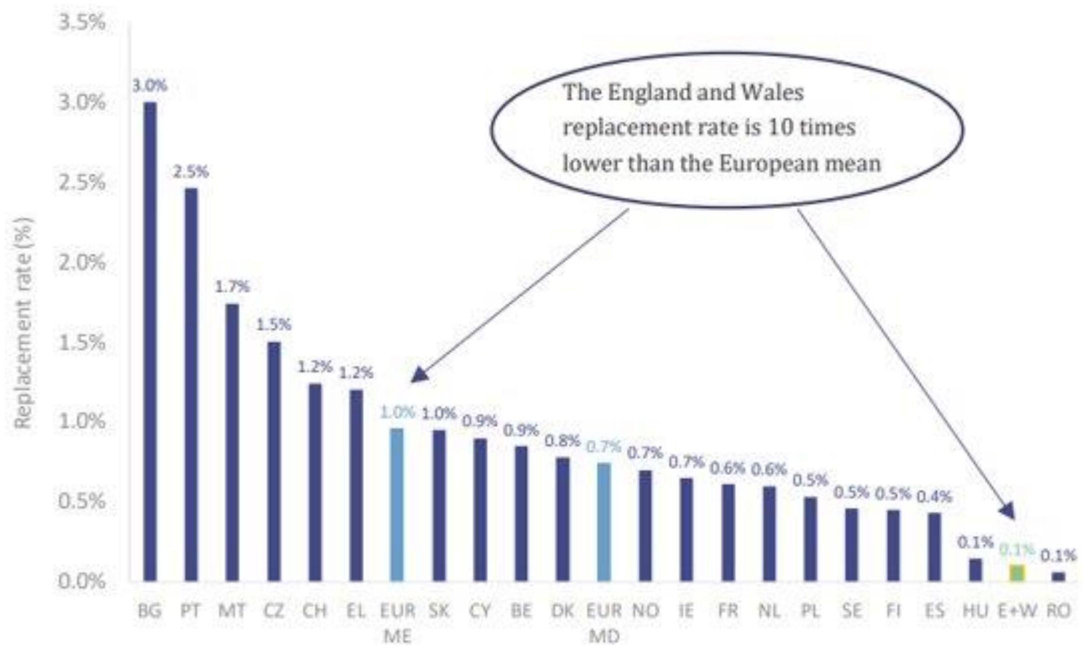
We have triangulated their results to arrive at a range of implied required additional Capital Maintenance. This range is roughly £150 million - £200 million per AMP above recent levels, and would take multiple AMPs to make up the perceived shortfall

## Economic Insight report for WaterUK[15]

In 2022 Water UK engaged Economic Insight to review approaches to sustainable asset maintenance. Within this paper several methods were used to assess the level of maintenance.

The report also examined the issue of past underspending of maintenance allowances. Each of these tests conclude that companies have consistently spent the allowances in their determinations, and that current maintenance levels appear too low.

Figure 1: Rate of replacement of water mains (see notes for time period)




## Economic life expectancy

In response to a data request from the National Infrastructure Commission we analysed our pipeline assets to derive the remaining economic life expectancy, defined by the NIC as "*the length of the period after which it is not cost effective to continue using the existing asset, and replacement or structural renewal would be required*". We therefore calculated the remaining asset life using a combination of failure rates and repair costs:

[15] https://www.water.org.uk/publication/options-for-a-sustainable-approach-to-asset-maintenance-and-replacement/

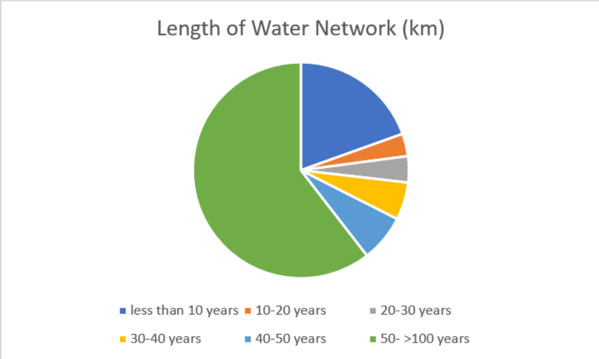
| Total length of water supply pipe network at 31 March 2021 (km) | |
|---|---|
| **Remaining economic life at 31 March 2021** | **Length of network (km)** |
| less than 10 years | 7,575 |
| 10-20 years | 1,308 |
| 20-30 years | 1,523 |
| 30-40 years | 2,184 |
| 40-50 years | 2,738 |
| 50-60 years | 23,461 |
| 60-70 years | |
| 70-80 years | |
| 80-90 years | |
| 90-100 years | |
| More than 100 years | |

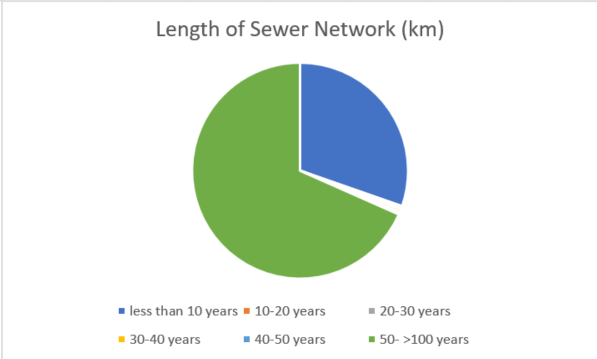
| Total length of sewer network at 31 March 2021 (km) | |
|---|---|
| **Remaining economic life at 31 March 2021** | **Length of network (km)** |
| less than 10 years | 23,371 |
| 10-20 years | 275 |
| 20-30 years | 136 |
| 30-40 years | 331 |
| 40-50 years | 259 |
| 50-60 years | 52,666 |
| 60-70 years | |
| 70-80 years | |
| 80-90 years | |
| 90-100 years | |
| More than 100 years | |

As Ofwat note in their response to the NIC[16] on this topic at a national level "*over 40% of the network is less than 30 years old and modern pipes can often last over 160 years*". We have reviewed our own data and confirmed that within our network 33% of our pipes are less than 30 years old (installed since 1993).

While the bulk of assets have significant remaining asset life as expected based on installed date, there are a large proportion with a relatively short economic life remaining, both for water mains and sewers, but particularly for sewers. This corroborates the case for some uplift in CM that the more detailed technical analysis earlier in the report is indicating.

[16] Letter to National Infrastructure Commission re: Water Company Asset Management - Ofwat




## Capital Maintenance compared with GMEAV

Whilst the broad equivalence test above compares capital maintenance with Regulatory Capital Value, some industries use a measure of annual Capital Maintenance spend as a proportion of Gross Modern Equivalent Asset Value (GMEAV) as a measure of the sustainability and efficiency of asset maintenance. GMEAV is calculated as the cost to build from new the modern equivalent asset base, using latest accepted technologies and today's prices. It is possible to infer from this measure the assumed asset life since capital maintenance renews assets and therefore if the renewal spend is one 20th of the replacement value then the assumed asset life is 20 years.

Our recent re-valuation of our asset base is summarised earlier in this report, with a total value of in excess of £68bn. We typically spend around £260m of capital maintenance spend per year. However, around a quarter of this is not spent on asset renewal and is instead allocated to capital spent on non-operational asset categories such as back-office IT systems, health and safety, vehicles, laboratories and recreation assets. Therefore, in order to compare renewal spend we reduce the amount to approximately £195m. When compared with the GMEAV described earlier the renewal spend is 0.3%, inferring an average asset weighted life of around 300 years. Whilst some water assets have long lives, this is unfeasibly long for the weighted average of all assets described in the GMEAV table earlier in this paper.

**Summary**

We have worked with Ofwat via the Cost Assessment Working Group (CAWG)[17] and via our responses to key consultations in preparation for PR24 such as Assessing Base Costs and the PR24 econometric models[18], consistently recommending forwards-looking approaches to determining allowances for capital maintenance. We will continue to work constructively to help the sector prepare for PR29, learning from the examples set by water regulators in Scotland[19] and Northern Ireland, and gathering additional data where required to derive sustainable levels of expenditure rather than assuming that historic run rates are adequate in the long term.

[17] PR24 working groups and workshops - Ofwat
[18] Econometric_base_cost_models_for_PR24_final.pdf (ofwat.gov.uk)
[19] 5 - Capital maintenance.pdf (wics.scot)

## Conclusion

The economic analysis cited above creates a strong presumption that increased capital maintenance spending will be required in the future if service levels to consumers are to be maintained. However, that increased spending requirement does not apply uniformly across the asset base and is differentiated by time with some requirements more urgent than others. This is the importance of this review of asset health. Through detailed engineering work and systematic, soundly based statistical analysis, we have been able to take a nuanced view of asset health investment requirements, with some areas already at sustainable levels and others requiring additional funding in the future. The main findings of this review are that:

1) We have prioritised maintenance of assets that directly provide service and impact service most immediately (generally mechanical and electrical assets such as pumps and treatment plants) and find that maintenance levels are broadly sustainable in the short to medium term for these asset types
2) We have effectively used operational measures such as pressure reduction, rapid response to improve service over time, but while this has enabled us to better target our capital maintenance spending and therefore maintain service, it has lead to a disconnect between underlying asset condition and asset health performance commitments
3) Current expenditure levels for longer lived assets that impact service with lower frequency but higher consequence (generally civil/structural assets such as pipelines and storage tanks) are insufficient to maintain long term performance and will need to increase beyond 2030

While this review has enabled a comprehensive assessment of asset condition across most of our asset base, there are areas where more information is required, which will be sought for PR29. Even so, the evidence already available here strongly suggests that an increase in capital maintenance will be required to maintain the health of the asset base. For AMP8 the priority area is confronting the increasing risks presented by climate change. While across most areas AMP8 spend can remain at AMP7 levels and maintain a stable position, that will not be feasible for AMP9, not least when the requirement to deal with longer lived assets is taken into account. For AMP8 the priority area is confronting the increasing risks presented by climate change.

**The central recommendation of this report is that continuation of current levels of performance requires future increases in capital maintenance activity in the period beyond 2030, as well as increased investment to tackle specific threats in the period 2025 to 2030.**

Through this exercise we believe we will be better prepared for future shocks and stresses, meaning reduced disruption to customers and the environment as a result of better planning and better asset management. We will continue to work constructively with Ofwat and other companies to evolve approaches to setting capital maintenance allowances using forward-looking approaches.

We look forward to working with our stakeholders and regulators to make this happen for the benefit of future generations.