Cost Appendix

Enhancement investment cases

Part B

Contents

Enhancement Programme Overview

Introduction

This appendix follows on from **AWF14a – Enhancement investment cases** part A. It summarises the relevant business cases and demonstrates how our proposed investments meet Ofwat's criteria to ensure value for money for customers.

Our enhancement programme totals £588m over AMP8 (including Accelerated and Transitional expenditure) and sets the basis for our long-term strategy as laid out in our LTDS. The programme has been developed and integrated with our Water Resources Management Plan (WRMP), Water Industry National Environment Programme (WINEP) and Drinking Water Inspectorate (DWI) programmes and our customers' views on discretionary improvements to service.

Over 70% of our investment is directly linked with the WINEP and WRMP statutory requirements. A further 15% addresses our raw water deterioration obligations from the DWI. Although there is limited discretion in the need to invest for these statutory requirements, we have challenged ourselves to ensure that all feasible options have been identified and considered; that our preferred solutions are efficient; that our customers' views support our preferred solution; and that we understand the cost benefits of our investments.

To protect the value to be delivered to our customers, we have used a combination of Performance Commitments and PCDs to monitor our performance and delivery. These are outlined in appendix **AFW19 – PCD Appendix**.

In developing our business cases, we have followed a rigorous and systematic approach of optioneering, economic analysis and investment justification that fully complies with Ofwat's, the EA's and the DWI's methodologies and benefit valuations.

Our enhancement programme has been built up from our detailed planning activities and is captured in individual business cases. In parallel, our long-term strategies, our customer research and stakeholder engagement have shaped and informed the programme. The enhancement programme has been aligned and optimised with our base investments throughout the process; both at the asset and site level and at the strategic levels. More information on our planning, optimisation and governance, processes and procedures are presented in **Chapter 7.6: Our Investment Planning Approach**. Yet further detail is laid out within appendix **AFW 8 – Our investment development process**.

Document structure

The following sections are grouped into our strategic theme areas, that align with our Long-Term Delivery Strategy. At the end of each section, we list the relevant business cases that make up the AMP8 investments for the theme. These business cases are then included in full at the back of this document.

For the sections relating to Net Zero, WINEP and WRMP please refer to **AWF14a – Enhancement investment cases**.

Strategy	Capex AMP8 (m)	Opex AMP8 (m)	Totex AMP8 (m)	%
Net Zero	£ 3	£ 1	£ 4	1%
WINEP	£ 143	£ 23	£ 166	28%
WRMP	£ 244	£ 35	£ 280	48%
Resilience	£ 29	£ 0	£ 29	5%
SEMD	£ 9	£ 3	£ 11	2%
Water Quality	£ 90	£ 4	£ 94	16%
Lead	£ 4	£ -	£ 4	1%
	£ 522	£ 66	£ 588	100%

Figure 1 - PR24 enhancement expenditure breakdown, including accelerated and transitional funding

Resilience

Ambition

Our long-term strategy is to ensure that our network and treatment facilities are resilient to a range of external risks including the impacts of climate change, pandemics, third-party activities etc. A first step in this process is to ensure that our asset health is sufficient to continue to operate and deliver service to customers. As such, we have developed a base investment programme to continue to maintain and improve the health of our existing assets. As part of this we have started to fully adopt Ofwat's Operational Resilience Framework and incorporate the principles and methods into our asset and corporate planning processes. We have already improved our asset health reporting, data capture and analysis, and we intend to make further significant improvements in this area in the future to improve how we identify and prioritise our future investments for resilience.

We started base programmes of work to maintain the resilience of our assets, which continue to mitigate against the risks that we currently face. This works will continue through AMP8 and beyond as part of our long-term strategy.

Our enhancement investments for resilience will go further and focus on protecting against the emerging climate change and third-party impacts on our ability to supply water. This covers four key areas: increasing our ability to transfer water supplies across the region (Connect 2050); identifying and addressing the weakest areas of our network (Single Points of Failure); taking measures to increase the life of our network assets (Water Network Resilience to Climate Change - Network Calming); and protecting our key treatment works from flooding events (Flood Resilience). In each of these areas, we continue to invest in our base resilience programmes, but we have now been able to identify the emerging risks and where and how best we can enhance our assets for the future. Strengthening in these areas all support our long-term resilience delivery strategy and, in particular, our climate change pathway. The investments also align and integrate with our WRMP, WINEP and SEMD strategies.

Customers have told us that the provision of safe, secure, supply of water is a high priority for them. When considering resilience in this context, customers generally focus on reducing bursts and leakage. Bursts can have a significant impact on customer satisfaction as they can lead to disruption, traffic congestion and pollution. Reducing leakage is consistently mentioned in any engagement that we do, and always features in the upper quartile of priorities. As such, there is strong support for investing to address resilience issues, particularly by proactively reducing bursts and leakage through network calming initiatives such as pressure optimisation and real-time monitoring.

AMP8 Investment

Our enhancement investments for resilience in AMP8 focuses on addressing the impacts of climate change. Our investments are continuations of our long-term programmes of work to continuously strengthen the network and treatment assets. These are:

- **Water Network Resilience to Climate Change (Network Calming):** A programme of initiatives including implementing: smart valves for all DMA boundary valves; permanent trunk main transient monitoring; and pressure management optimisation
- **Single Points of Failure (SPOF):** Undertake a programme of work to identify, prioritise and resolve the most critical single points of failure
- **Flood Resilience:** A programme of works to review and evaluate flood protection measures and to implement physical protection on our above ground assets such as: repositioning electrical distribution cabinets; raising the headworks of boreholes; sealing of ducts into buildings & chambers; installing flood covers over ventilation louvres; drainage improvement works; installing flood protection doors; procuring flood vehicles; and training
- **Connect 2050 (part):** To provide additional cells at the Hadham Mills (20 Ml) and the Hills (10 Ml) service reservoirs. Our Connect 2050 resilience programme forms part of our wider Connect 2050 programme that also integrates with our WRMP and WINEP programmes

AMP8 Spend	2025-26	2026-27	2027-28	2028-29	2029-30	Total
Capex (£m)	3.68	4.69	6.92	7.74	5.63	**28.66**
Opex (£m)	0.00	0.00	0.02	0.01	0.02	**0.05**
Totex (£m)	3.68	4.69	6.94	7.75	5.65	**28.71**
Drivers						
100%	Resilience					
Benefits						
Leakage (Ml/d) Water Supply Interruptions (property mins) Mains Repairs (number) Loss of Supply Capacity (Ml/d) Loss of Production Capacity (Ml/d) Climate Change Interruptions (mins)						
Economic Analysis						
NPV Costs (£m) (2025-55)		**24.7**	NPV Benefits (£m)(2025-55)			**35.5**
NPV (£m) (2025-55)		**10.8**	Benefit / Cost Ratio			**1.4**

Six Capitals					
Natural	Social	Financial	Manufact.	Human	Intellectual
	★ ★ ★	★	★ ★		★
Performance					
Customers are protected by the leakage, water supply interruptions and main repairs Performance Commitments and PCDs for the other areas of investment. The PCDs cover number of properties protected by single point of failure removal and the additional capacity provided by our Connect 2050 and Flood Resilience schemes.					

Justification

Customers have indicated support for investing in resilience particularly in reducing bursts and leakage. However, our programme has to be affordable and deliverable and we, therefore, need to focus on the areas that provide the highest benefits to customers first. We need to be confident that our investments are no regrets and that we only invest at a rate that matches the increasing risk.

Estimating the risks and how best to mitigate these is complex. We have, therefore, undertaken economic assessments in each area to select the best value solutions and optimise the level of investment in AMP8. Our economic analysis builds upon our Risk and Value workshops that undertake in-depth assessments to better understand the resilience risks and how best, and when, to mitigate these.

We have separately assessed and optimised each of the four areas of investment: Connect 2050; SPOF; Water Network Resilience to Climate Change (Network Calming) and Flood Resilience. In each case, we have selected the best value option, which has generally also been the least cost option. In most areas, it is shown to better to invest less and focus on the highest risk areas first, and then invest more in later AMPs when our understanding has improved. We have found that all of our preferred options are cost beneficial, particularly the network calming programme which shows a very strong cost benefit. We have considered options to increase the investment levels, but, although these are also cost beneficial, the uncertainties and level of benefits are not shown to be as attractive for customers.

We appreciate that it is difficult to forecast climate change and other risks and so our approach and investment has been conservative. We believe that the best way to mitigate against these risks is with an on-going long-term programme of work that focuses on the more immediate and highest risk areas and learns and adapts over time.

Meeting the Enhancement Criteria

Enhancement Criteria	
Need for Enhancement Investment	
Is there evidence that the proposed enhancement investment is required? (includes alignment agreed strategic planning framework or environmental programme where relevant)	We are seeing more and more impacts of the changing climate on our ability to deliver service Our long-term delivery strategies and core pathways forecast a clear need to address the impacts of climate change
Is the scale and timing of the investment fully justified, and for statutory deliverables is this validated by appropriate sources (for example in an agreed strategic planning framework)?	Our AMP8 investments are a continuation of our long-term strategies and programme of works We have considered many options and used our Risk and Value and economic assessments to optimise the timing and levels of investment against the risks that we face
Does the proposed enhancement investment or any part of it overlap with activities to be delivered through base, and where applicable does the company identify the scale of any implicit allowance?	We are investing across our asset base to improve our asset health and hence the net resilience of our network and treatment assets Our enhancement investments only relate to mitigating against future climate change impacts
Does the need and/or proposed enhancement investment overlap or duplicate with activities already funded at previous price reviews?	No
Is the need clearly identified in the context of a robust long-term delivery strategy within a defined adaptive pathway?	This work supports our long-term resilience strategy, and the core, climate change pathway in particular Options have been selected to ensure no regret investments and to enable adaptive delivery approach to be adopted
Where appropriate, is there evidence that customers support the need for investment (including both the scale and timing)?	Customers support investing in resilience to ensure future water supply. Their focus is generally to reduce leakage and bursts to achieve this We have designed our programme to align with our customers' views
Is the investment driven by factors outside of management control? Is it clear that steps been taken to control costs and have potential cost savings (e.g. spend to save) been accounted for?	Yes, all resilience investment is targeted to address externally driven risk from climate change, flooding or third party damage. Our Green Book approach ensures accurate NPV calculation with in period spend to save accounted for within base costs.
Best Option for Customers	
Has the company considered an appropriate range of options to meet the identified need?	Yes. A wide-range of options have been considered and optimised to determine best level of investment within the AMP
Has a robust cost–benefit appraisal been undertaken to select the proposed option? There should be evidence that the proposed solution represents best value for customers, communities and the environment over the long term? Is third-	Yes. We have undertaken a detailed economic assessment using the Ofwat methodologies and benefit valuations

party technical assurance of the analysis provided?	Our analysis has compared many options including a preferred and least cost option using our risk and value processes Our economic analysis approach has been assured by third-parties
In the best value analysis, has the company fully considered the carbon impact (operational and embedded), natural capital and other benefits that the options can deliver? Has it relied on robustly calculated and trackable benefits when proposing a best value option over a least cost one?	Operational and embedded carbon and natural capital impacts have been qualitatively assessed though the option assessments
Is the impact (incremental improvement) of the proposed option on the identified need been quantified, including the impact on performance commitments where applicable?	We have consistently used the Ofwat benefit valuations and benefit measure estimate methodologies in our economic analysis
Have the uncertainties relating to costs and benefit delivery been explored and mitigated? Have flexible, lower risk and modular solutions been assessed – including where forecast option utilisation will be low?	Many options have been considered and the uncertainties in costs and benefits explored in our preferred option selection and our sensitivity analysis Our economic analysis approach has been conservative by design to account for the inherent uncertainties in the analysis
Where appropriate, has the company secured appropriate third-party funding (proportionate to the third-party benefits) to deliver the project?	This is not applicable for this business case
Has the company appropriately considered the scheme to be delivered as Direct Procurement for Customers (DPC) where applicable?	Connect 2050 (in its entirety, not just the resilience component) has been robustly assessed for DPC (in combination with our sustainability reductions programme to achieve the programme scalability threshold). It has been found not to be suitable (please see the DPC appendix)
Where appropriate, have customer views informed the selection of the proposed solution, and have customers been provided sufficient information (including alternatives and its contribution to addressing the need) to have informed views?	We have engaged with customers and accounted for their views in the design of the programme
Cost Efficiency	
Is it clear how the company has arrived at its option costs? Is there supporting evidence on the calculations and key assumptions used and why these are appropriate?	The costs for the schemes have been developed from the bottom-up and with unit cost curves
Is there evidence that the cost estimates are efficient (for example using similar scheme outturn data, industry and/or external cost benchmarking)?	The costs derived for the options are based on the AMP6 and AMP7 costs and are deemed to be accurate and efficient. Please see the Costing & Investment Portfolio Optimisation appendix
Does the company provide third-party assurance for the robustness of the cost estimates?	Please see the Costing & Investment Portfolio Optimisation appendix

Customer Protection	
Are customers protected (via a price control deliverable or performance commitment) if the investment is cancelled, delayed or reduced in scope?	Customers are protected through the leakage, mains repairs and interruptions to supply Performance Commitments We have also designed a PCD to protect customers based upon the additional number of properties protected against climate change risks as well as flooding risks to sites.
Does the protection cover all the benefits proposed to be delivered and funded (e.g. primary and wider benefits)?	Yes
Does the company provide an explanation for how third-party funding or delivery arrangements will work for relevant investments, including how customers are protected against third-party funding risks?	This is not applicable for this business case

Supporting Business Cases

- Water Network Resilience to Climate Change (Through Network Calming): Water Network Resilience to Climate Change.docx
- Flood Resilience: Flood Resilience.docx
- Single Points of Failure: Resilience Single Points Of Failure.docx
- Connect 2050: Connect 2050.docx

SEMD

Ambition

The Water Industry Act of 1991 requires Water Undertakers to maintain essential services at all times. Section 208 of the Act gives the Secretary of State the authority to issue both general and specific directions to Water Undertakers in the interests of national security and resilience.

The DWI's Security and Emergency Measures (Water and Sewerage Undertakers) Direction (SEMD, 2022) is the principle general Direction issued under Section 208 of The Water Industry Act. Water Undertakers are legally obliged "to have regard" to any guidance, procedures, requirements, and policies relating to civil emergencies and national security that are notified to them by the Secretary of State.

The Direction requires UK Water Companies to make plans for the provision of potable water and national security. The recent SEMD requires a some significant changes to be made, with more stringent requirements for water supply during emergencies and cyber security measures.

We have found that our customers do not automatically identify resilience as an area of high concern especially when relating external factors, such as climate change, to the impact of delivering a secure supply of water. They generally think of bursts or leakage when they think about resilient supplies. They do, however, expect that we plan ahead and mitigate the risks that will impact on water supply.

Our policy and on-going ambition is to ensure that all of our sites, people, processes and suppliers remain resilient and compliant with the SEMD requirements. As such, we will continue to invest and comply with the SEMD requirements, and any future changes that are made, and by accounting for population growth and climate change. Our strategy is to ensure that customers always have access to alternative water during incidents and emergencies; mitigating vulnerabilities on our sites; and enhancing both our physical and cyber security measures as threats evolve and change.

AMP8 Investment

The need for investment is to ensure continued compliance and enhancement with the SEMD Direction. Each of the three key areas: emergency planning, physical and personnel security and cyber security have undertaken in-depth assessments against the respective SEMD requirements following the respective methodologies. Detailed risk assessments have been undertaken and followed up with our Risk and Value workshops. Options and solutions have then been identified and costed for economic assessment. Many of the requirements are statutory, albeit risk-based, which gives us some limited flexibility on how best to invest.

We have used our risk assessments and economic analysis to identify the best value options to meet our statutory obligations.

Our enhancement investments for AMP8 are summarised as:

- **Emergency Planning:** provision of four water tankers; a new storage area for bottled water; a new lorry to transport bottled water; three mobile power generators; satellite communications and the associated enabling works
- **Physical and Personnel Security:** Security upgrades at the newly designated CNI sites [redacted]
- **Cyber Security:** Improve the resilience and security of the systems that support the essential services. The improvement is necessary to mature the overall security controls and to meet stringent regulatory requirements for Critical National Infrastructure (CNI) company and an Operator of Essential Services

Additional details of the investment activities are presented in the respective business cases.

AMP8 Spend		2025-26	2026-27	2027-28	2028-29	2029-30	Total
Capex (£m)		2.50	1.82	1.73	1.38	1.40	**8.83**
Opex (£m)		0.12	0.29	0.70	0.70	0.77	**2.58**
Totex (£m)		2.62	2.11	2.43	2.08	2.17	**11.41**
Drivers							
60%		Security - SEMD					
40%		Security - Cyber					
Benefits							
Health and Safety (incidents) Capex and Opex Savings (£m)							
Economic Analysis							
NPV Costs (£m) (2025-55)			**9.7**	NPV Benefits (£m)(2025-55)			**14.1**
NPV (£m) (2025-55)			**4.4**	Benefit / Cost Ratio			**1.5**
Six Capitals							
Natural	Social	Financial	Manufact.	Human	Intellectual		
	★ ★ ★	★ ★	★	★			
Performance							
Due to the low materiality of total costs and associated bill impact, we do not propose a PCD for customer protection, however all SEMD investments will be subject to significant regulatory scrutiny by the DWI who support our SEMD investments.							

Justification

Compliance with the SEMD is a statutory requirement and our enhancement investment has been targeted to meet this objective. Our economic analysis approach has shown that our investments are cost beneficial and customers have indicated that mitigating against extreme risks to water supply is expected from us.

We are currently required to supply a minimum of 10 litres per person per day to 20,000 people i.e. 200,000 litres of water based on a worst case scenario. However, from the start of AMP8, all companies must base their plans for alternative water on their local context and population, having regard to national reasonable worst-case scenarios. As a minimum, companies should plan to provide alternative water for 1.5% of their domestic population. This increases our reasonable worst case to 520,000 litres. We have demonstrated recently during the December '22 freeze/thaw that we were just able to supply the 200,000 litres of alternative water. As such, we need to invest to become compliant with the new requirement.

Security threats are dynamic by nature, as the threat vector changes and evolves over time, existing physical and electronic measures must be capable of meeting new or increased threat levels identified during actual incidents. or upon the guidance issued by the UK Government Security Services so that necessary levels of protection are maintained at all times. Two of our sites have been designated as CNI sites and require investment to comply with the SEMD requirements.

Whilst risks from unauthorised access to Critical National Infrastructure, water supply process, storage and distribution elements, have been suitably mitigated by our previous investments, our on-going site security risk assessments and repeated incidents has identified a number of vulnerabilities requiring further investment in physical and personnel security measures. These risks will be addressed as part of our base investments.

Critical infrastructure companies like Affinity Water face persistent and increasingly sophisticated destructive cyber campaigns that threaten services, and ultimately our customers' data and privacy. We are seeing an increase in attacks by a well-resourced threat actor with the potential to cause physical damage to industrial control systems, and in this case, to water treatment facilities, leading to disruption to water supply, longer recovery period and cost. In essence, our risks are increasing and we need to invest to protect against these risks.

Meeting the Enhancement Criteria

Enhancement Criteria	
Need for Enhancement Investment	
Is there evidence that the proposed enhancement investment is required? (includes alignment agreed strategic planning framework or environmental programme where relevant)	The investment addresses the statutory and regulatory requirements and the non-statutory drivers. It is supported by our key stakeholders and aligns with their long-term ambitions
Is the scale and timing of the investment fully justified, and for statutory deliverables is this validated by appropriate sources (for example in an agreed strategic planning framework)?	The investment is required in AMP8 to address the new SEMD obligations
Does the proposed enhancement investment or any part of it overlap with activities to be delivered through base, and where applicable does the company identify the scale of any implicit allowance?	We are investing in base to continue to strengthen our physical and personnel security, cyber security and emergency planning Our enhancement investments are required to meet the new obligations
Does the need and/or proposed enhancement investment overlap or duplicate with activities already funded at previous price reviews?	No
Is the need clearly identified in the context of a robust long-term delivery strategy within a defined adaptive pathway?	This work supports our ambition to continue to fully comply with the SEMD requirements and to ensure security of supply to customers against extreme events
Where appropriate, is there evidence that customers support the need for investment (including both the scale and timing)?	We have found that customers expect us to plan and mitigate against extreme events to ensure secure water supplies, albeit their focus is generally related to resolving leakage and bursts
Is the investment driven by factors outside of management control? Is it clear that steps been taken to control costs and have potential cost savings (e.g. spend to save) been accounted for?	No
Best Option for Customers	
Has the company considered an appropriate range of options to meet the identified need?	A wide-range of options have been identified and considered through our Risk and Value assessments
Has a robust cost–benefit appraisal been undertaken to select the proposed option? There should be evidence that the proposed solution represents best value for customers, communities and the environment over the long term? Is third-party technical assurance of the analysis provided?	We have undertaken a detailed economic assessment using the Ofwat methodology. We have used industry standard (ONS) benefit valuations for health and safety benefits Our analysis has compared many options including a preferred and least cost option Our economic analysis approach has been assured by third-parties
In the best value analysis, has the company fully considered the carbon impact (operational and embedded), natural capital and other benefits that the options can deliver? Has it relied on robustly calculated and trackable benefits when	We have qualitatively assessed the carbon impacts in our Risk and Value assessments and used these to inform our options

proposing a best value option over a least cost one?	
Is the impact (incremental improvement) of the proposed option on the identified need been quantified, including the impact on performance commitments where applicable?	The main objective and impact is to ensure compliance. We have also estimated the impact of the investments on the risks
Have the uncertainties relating to costs and benefit delivery been explored and mitigated? Have flexible, lower risk and modular solutions been assessed – including where forecast option utilisation will be low?	Many options have been considered and the uncertainties in costs and benefits explored in our preferred option selection and our sensitivity analysis Our economic analysis approach has been conservative by design to account for the inherent uncertainties in the analysis
Where appropriate, has the company secured appropriate third-party funding (proportionate to the third-party benefits) to deliver the project?	This is not applicable for this business case
Has the company appropriately considered the scheme to be delivered as Direct Procurement for Customers (DPC) where applicable?	This is not applicable for this business case
Where appropriate, have customer views informed the selection of the proposed solution, and have customers been provided sufficient information (including alternatives and its contribution to addressing the need) to have informed views?	We have engaged with customers and accounted for their views in the design of the programme
Cost Efficiency	
Is it clear how the company has arrived at its option costs? Is there supporting evidence on the calculations and key assumptions used and why these are appropriate?	The cost numbers used to formulate the proposal have been taken from current cost of services, using data taken from procurement, existing contracts and research Therefore the confidence rating in the costs is mid to high
Is there evidence that the cost estimates are efficient (for example using similar scheme outturn data, industry and/or external cost benchmarking)?	The costs derived for the options are based on the AMP6 and AMP7 costs and are deemed to be accurate and efficient. Please see the Costing & Investment Portfolio Optimisation appendix
Does the company provide third-party assurance for the robustness of the cost estimates?	Please see the Costing & Investment Portfolio Optimisation appendix
Customer Protection	
Are customers protected (via a price control deliverable or performance commitment) if the investment is cancelled, delayed or reduced in scope?	SEMD is covered by DWI obligation, in addition it does not meet the materiality threshold. This encompassed all outputs and outcomes of the investments.
Does the protection cover all the benefits proposed to be delivered and funded (e.g. primary and wider benefits)?	
Does the company provide an explanation for how third-party funding or delivery arrangements will work for relevant investments, including how	This is not applicable for this business case

customers are protected against third-party funding risks?	

Supporting Business Cases

- SEMD Emergency Planning: Emergency Planning.docx
- SEMD Physical and Personnel Security: Physical and Personnel Security.docx
- SEMD Cyber Security: Cyber Security.docx

Raw Water Deterioration

Ambition

Our customers and other stakeholders expect us to continue to actively manage any deterioration in raw water quality. Our long-term strategy supports this and aligns with the objectives of our WRMP and environmental programmes. As such, we will continue to invest to manage water quality at source through our WINEP, by strengthening our network, and also by upgrading the treatment facilities at our water treatment works where they are at risk. Our ambition is to continue to safeguard our industry leading water quality performance and to reduce the risk of interruptions to supply, resulting from water quality issues, over the long-term.

The Drinking Water Inspectorate (DWI) has issued Section 28(4) Notices which require the improvement of the treatment levels at the Egham and Iver WTWs to protect against *Cryptosporidium* outbreaks, at Broome, Kingsdown, and Stansted for nitrate reduction, and at Holywell for PFAS removal. These form statutory requirements that could result in enforcement proceedings under Section 18 of the Water Industry Act 1991 if not addressed in AMP8. We received letters of support from the DWI at the end of August covering all the remaining water quality schemes and have sent draft Notices to the DWI at the end of September for their approval.

Some of the groundwater aquifers that we abstract from have been found to have multiple Perfluoroalkyl and Polyfluoroalkyl Substances (PFAS) compounds present. This is usually the result of diffuse or point-source pollution events which took place in the past, although may also be related to on-going activities. In January 2021, the DWI published their revised guidance for the parameters PFAS and PFOA. This guidance reduced the value for wholesomeness (effectively the Permitted Concentration Value, PCV) for PFOS from 1 µg/l to 0.1 µg/l and for PFOA from 5 µg/l to 0.1 µg/l. In July 2022, the wholesomeness value was extended to 45 other PFAS (IL 03/22). As a result, we have reviewed our risk assessments across all sources and drinking water supplies and identified the following sites require risk mitigation measures: Wheathampstead, Blackford, Bowring & Baldock Road, and Holywell. Anglian Water have also carried out a similar review and have identified that Ardleigh WTW, an asset of shared ownership (50:50) between Anglian Water and Affinity Water, is also at risk and requires investment.

The concentration of nitrate is increasing in the raw water abstracted at our Kingsdown, Broome and Stansted WTWs. This has already resulted in sites having to be turned off during periods of high nitrate levels. Our modelling indicates that this issue will not begin to decrease for many years to come. The Stortford supply area, that is supplied by Stansted WTW, has a low resilience, due to its limited storage and the configuration of the network. Although, there is a provision in the WINEP for some catchment management schemes in this area for AMP8, the benefit from these schemes will only be realised in the long-term and will not reduce the amount of nitrate already present in the soil layers from historic agricultural use.

It is critical that investment is made in AMP8 at all of the affected sites to safeguard the supply-demand balance, protect and improve service levels to consumers, and to reduce the risk of unplanned outages, low pressure and interruptions to supply.

We have also considered going beyond the statutory requirements. Our qualitative customer research sessions indicated that customers generally preferred avoiding deteriorated service levels compared to making aesthetic water quality improvements. Household customers only modestly valued aesthetic improvements. Overall, our respondents felt that Affinity Water's services are good value for money and were generally satisfied with levels of services that they receive for water quality. There is no great desire for us to invest in improving aesthetic water quality.

AMP8 Investment

The DWI Notices require Affinity Water to address the deterioration in raw water quality, and make investments in AMP8 to maintain wholesome water. In addition, many of these schemes have been approved for accelerated funding. The programme consists of a range of different solutions that include:

- **Iver WTW:** A validated UV irradiation system for the inactivation of *Cryptosporidium* oocysts (delivery AMP7); optimisation of the clarification process; additional rapid gravity filters to treat full output; covers for the GAC filters; and the upgrade of the wastewater treatment plant to improve water recirculating to the head of the works
- **Egham WTW:** A validated UV irradiation system for the inactivation of *Cryptosporidium* oocysts (delivery AMP7); optimisation of the clarification process; upgrade of the RGF process; and the upgrade of the wastewater treatment plant to improve water recirculating to the head of the works
- **PFAS Schemes:** Works at Baldock Road and Bowring, Blackford, Holywell and Wheathampstead, and our share of Ardleigh with Anglian Water.
- **Nitrate Schemes:** Works to provide ion-exchange treatment at Kingsdown and Broome WTWs and installation of a new trunk main and additional boosters to provide extra resilience for the Stortford area.

AMP8 Spend	2025-26	2026-27	2027-28	2028-29	2029-30	Total
Capex (£m)	28.82	32.05	19.83	8.95	0.00	**89.65**
Opex (£m)	0.20	0.29	0.81	1.37	1.50	**4.17**
Totex (£m)	29.02	32.34	20.64	10.32	1.50	**93.82**
Drivers						
100%	Addressing raw water quality deterioration (grey solutions)					
Benefits						

Loss of Production Capacity (Ml/d) Compliance Risk Index (score) Capex and Opex Savings (£m)					
Economic Analysis					
NPV Costs (£m) (2025-55)		**104.6**	NPV Benefits (£m) (2025-55)		**226.4**
NPV (£m) (2025-55)		**121.8**	Benefit / Cost Ratio		**2.2**
Six Capitals					
Natural	**Social**	**Financial**	**Manufact.**	**Human**	**Intellectual**
	★ ★ ★	★	★ ★		
Performance					
We have designed PCDs to protect customers based upon the additional production capacity at our sites: Iver & Egham; PFAS sites; and Nitrate sites					

Justification

Our investment programme to manage raw water deterioration is required to address the statutory requirements and the DWI Notices. It is required to be completed within AMP8, and six of the schemes have accelerated funding to achieve the outputs as early as practically possible.

The DWI and customers support the investments, which align with our long-term strategic intent to continue to provide high-quality water supplies to customers. Our research shows that customers inherently trust us to manage water quality risks and make decisions about technology selection. They also have a strong expectation for us to meet our regulatory obligations at all times. They do not support investments in making aesthetic water quality improvements.

We have developed a wide-range of options, which have been through our Risk and Value workshops. The set of selected options have then been subjected to economic assessments to determine the cost benefits and to select the preferred options. All of our schemes have been shown to be cost beneficial and most are strongly cost beneficial. The nitrates schemes are less cost beneficial because the unit cost of treatment is higher than for *Cryptosporidium* and PFAS treatment facilities. In essence, these schemes provide security of supply, which is highly beneficial to customers. They are statutory requirements and failure to invest would result in fines and the need to undertake the work anyway but at higher cost.

Meeting the Enhancement Criteria

Enhancement Criteria	
Need for Enhancement Investment	
Is there evidence that the proposed enhancement investment is required? (includes alignment agreed strategic planning framework or environmental programme where relevant)	Strong evidence has been provided for the water quality risk change. The investment addresses the statutory and regulatory requirements. It is supported by our key stakeholders and aligns with their long-term ambitions
Is the scale and timing of the investment fully justified, and for statutory deliverables is this validated by appropriate sources (for example in an agreed strategic planning framework)?	The investment has been agreed for AMP8 with the DWI and other stakeholders to meet the identified risks and issues
Does the proposed enhancement investment or any part of it overlap with activities to be delivered through base, and where applicable does the company identify the scale of any implicit allowance?	No
Does the need and/or proposed enhancement investment overlap or duplicate with activities already funded at previous price reviews?	No
Is the need clearly identified in the context of a robust long-term delivery strategy within a defined adaptive pathway?	This work supports our stakeholders' long-term strategies, and our long-term strategy to continue to provide wholesome water to customers Our investments are required to be completed in AMP8 to meet our obligations
Where appropriate, is there evidence that customers support the need for investment (including both the scale and timing)?	We have found that customers support the need to proactively manage water quality risks and issues and to comply with our statutory obligations. They trust us to select the best water quality treatment solutions We also tested customers' preferences for improving aesthetic water quality and found that customers were generally content with the current levels of service and had a preference for maintaining bills at current levels We have designed our programme to align with our customers' views
Is the investment driven by factors outside of management control? Is it clear that steps been taken to control costs and have potential cost savings (e.g. spend to save) been accounted for?	Investment is needed to address the DWI notices. However, the planning and design of the schemes has been under our control, albeit with consultation with the DWI
Best Option for Customers	
Has the company considered an appropriate range of options to meet the identified need?	A wide-range of options have been considered with detailed planning, Risk and Value workshops and with economic assessments. Our options and solutions have been discussed and verified with our stakeholders

Has a robust cost–benefit appraisal been undertaken to select the proposed option? There should be evidence that the proposed solution represents best value for customers, communities and the environment over the long term? Is third-party technical assurance of the analysis provided?	We have undertaken detailed economic assessments for each scheme using Ofwat methodologies and benefit valuations Our analysis has compared many options including a preferred and least cost option Our economic analysis approach has been assured by third-parties
In the best value analysis, has the company fully considered the carbon impact (operational and embedded), natural capital and other benefits that the options can deliver? Has it relied on robustly calculated and trackable benefits when proposing a best value option over a least cost one?	We have considered the operational embedded carbon and natural capital impacts in our assessments to select our preferred options
Is the impact (incremental improvement) of the proposed option on the identified need been quantified, including the impact on performance commitments where applicable?	We have consistently used the Ofwat benefit valuations and benefit measure estimate methodologies in our economic analysis
Have the uncertainties relating to costs and benefit delivery been explored and mitigated? Have flexible, lower risk and modular solutions been assessed – including where forecast option utilisation will be low?	Many options have been considered and the uncertainties in costs and benefits explored in our preferred option selection and our sensitivity analysis Our economic analysis approach has been conservative by design to account for the inherent uncertainties in the analysis We have used study results to support our benefit estimates
Where appropriate, has the company secured appropriate third-party funding (proportionate to the third-party benefits) to deliver the project?	This is not applicable for this business case
Has the company appropriately considered the scheme to be delivered as Direct Procurement for Customers (DPC) where applicable?	This is not applicable for this business case
Where appropriate, have customer views informed the selection of the proposed solution, and have customers been provided sufficient information (including alternatives and its contribution to addressing the need) to have informed views?	We have engaged with customers and accounted for their views in the design of the programme
Cost Efficiency	
Is it clear how the company has arrived at its option costs? Is there supporting evidence on the calculations and key assumptions used and why these are appropriate?	The costs for each option have been developed through detailed planning and by using a combination of our unit cost models and costs from previous known work and schemes
Is there evidence that the cost estimates are efficient (for example using similar scheme outturn data, industry and/or external cost benchmarking)?	The costs derived for the options are based on the AMP6 and AMP7 costs and are deemed to be accurate and efficient. Please see the Costing & Investment Portfolio Optimisation appendix for more information
Does the company provide third-party assurance for the robustness of the cost estimates?	The cost estimates have been validated using consultant cost models, checked internally and all cases subject to external review. Please see the

	Costing & Investment Portfolio Optimisation appendix for more information
Customer Protection	
Are customers protected (via a price control deliverable or performance commitment) if the investment is cancelled, delayed or reduced in scope?	Customers will be protected through a PCD for this project, which will be aligned with the requirements set out by the DWI in the Section 28(4) Notice. The PCD will be based on the production capacity that will be protected by our enhanced treatment facilities and network improvements
Does the protection cover all the benefits proposed to be delivered and funded (e.g. primary and wider benefits)?	Yes
Does the company provide an explanation for how third-party funding or delivery arrangements will work for relevant investments, including how customers are protected against third-party funding risks?	Third party funding not applicable

Supporting Business Cases

- Iver Surface Works: Iver Surface Works DWI.docx
- Egham Surface Works: Egham Surface Works DWI.docx
- PFAS Sites: Raw Water Deterioration PFAS Sites.docx
- PFAS - Ardleigh: Raw Water Deterioration PFAS Ardleigh.docx
- Nitrates Sites: Raw Water Deterioration Nitrates Sites.docx

Lead Replacement

Ambition

The presence of concentrations of lead in drinking water is a known health issue. World Health Organisation (WHO) and European Food Safety Authority (EFSA) agree that there is no safe lower limit of lead that should be in water supplies. Health effects are varied but most are acutely felt by small children (including unborn babies) as exposure to low-level lead concentrations are known to inhibit brain development. In adults it may impair kidney, heart and circulatory health. Adverse health effects from ingestion of drinking water which contains even very small amounts of lead, cannot be ruled out. This evidence has driven the first step in what will be a continuous decrease over time in the regulatory limit in the lead water quality standard, from 10 µg/l to 5 µg/l in the current recast of the EU Drinking Water Directive.

We have engaged with our customers to assess their level of support for lead replacement. Out of the five key investment areas tested with customers (reducing abstraction and environmental restoration, carbon net zero, improving resilience, lead replacement, and hard water) lead replacement ranked as the highest priority in a representative study. Just over half of respondents were aware that there are lead pipes in the Affinity area and most of those had either checked for them or had them removed. 48% of participants in the study opted for the highest possible level of investment when allocating spend to the different investment areas

The current permissible lead limit is 10µg/l. The DWI would like to see this reduced to 5 µg/l by 2050, essentially achieving "lead free" drinking water supply. This would require large-scale lead pipe replacements. Defra does not yet support this target. In fact, in February 2022, Defra set its strategic priorities for Ofwat for the next five-year period, which stated that investment should focus on trialling different approaches to reducing exposure to lead and removing lead pipes.

In the short-term, we will continue to deliver high-quality drinking water through our base activities and we will continue to invest to achieve the 10 µg/l target. However, our ambition for removing lead pipes aims to go well beyond this, supporting our ambition to exceed customers' expectations for drinking water. Our lead strategy ambition is to strive towards a 'lead free society' and to end orthophosphate dosing. We believe that the health benefits will ultimately be shown to be worth the investment.

In the short-term, we must firstly better understand how best to replace the lead pipes and the benefits of doing so. Key elements of the trials will be to reduce the units costs of pipe replacement; how best to target the replacements; and how to work with the community. The results from the trials will inform the debate as to whether the targets should be changed or not and if so when.

In the longer term, we aim to remove all lead supply and communication pipes from customer properties in our eleven highest risk zones by 2050. We will combine this with continuing to replace supply and communications pipes at any property where lead is found at levels higher than 5µg/l and any property where the customer has replaced their own lead supply pipe.

AMP8 Investment

Our AMP8 lead strategy has been informed by activity from AMP6 and AMP7 and taken into account the differing regulatory views and approaches. It follows Defra's short-term approach. It also supports our long-term delivery strategy and DWI's longer-term target.

Our base investment will continue to target and replace properties with lead levels above 10µg/l. Our enhancement investments for AMP8 cover the following areas:

- To offer properties suffering a lead sample failure of 5ug/l or above a free communications and supply pipe renewal to the compliance point. We estimate that this will result in 1,000 properties being replaced over AMP8
- Undertake small scale innovation trials, aligned to the wider Ofwat approach, seeking to drive unit cost reductions and targeted approach on the more difficult properties

AMP8 Spend	2025-26	2026-27	2027-28	2028-29	2029-30	Total
Capex (£m)	0.41	0.81	1.00	0.99	0.79	**4.00**
Opex (£m)	0.00	0.00	0.00	0.00	0.00	**0.00**
Totex (£m)	0.41	0.81	1.00	0.99	0.79	**4.00**
Drivers						
56%	Lead communication pipes replaced or relined					
22%	External lead supply pipes replaced or relined					
22%	Internal lead supply pipes replaced or relined					
Benefits						
Lead Health Improvements (properties)						
Economic Analysis						
NPV Costs (£m) (2025-55)	**3.2**	NPV Benefits (£m) (2025-55)	**3.5**			
NPV (£m) (2025-55)	**0.3**	Benefit / Cost Ratio	**1.1**			
Six Capitals						

Natural	Social	Financial	Manufact.	Human	Intellectual
	★ ★ ★		★ ★		★

Performance
We have designed a PCD to protect customers based upon the delivery of the number of properties where we replace lead supply and communication pipes within the AMP

Justification

We have a strong long-term ambition to remove lead pipes from our customers, which aligns to WHO and DWI perspectives, and is the right thing to do for society. However, Defra is clear that the time is not right to invest heavily in pipe replacements as the benefits are not clear and customers do not show great desire to tackle the problem at the moment.

Our own economic assessment shows that the health benefits are currently marginal for both supply pipe replacements, and supply and communication pipe replacements. However, we expect that future technical developments in pipe replacements, research into health impacts, and societal awareness is likely to change the cost benefits over time. Our trials should also help with how we can best target our investments to those at highest risk and hence realise higher benefits. It therefore makes sense to adopt the conservative approach, as proposed by Defra, and undertake trials for AMP8.

We are, and will continue to be, an active contributor to the Industry Lead Steering Group. As part of this, we will continue to lead the Innovation Working Group that looks for new and innovative approaches to delivering lead activity into the future. Our current approach with active trials renewing communications and supply pipes is already considered to be one of the leading delivery approaches. We intend to build upon this in AMP8.

Our long-term delivery strategy builds upon this, and aims to increase investment levels as and when the time is right to do so. Overall, this approach provides a coherent approach to the challenge of lead in the short, medium and long-term that aligns with our customers' and stakeholders' views. It utilises an adaptive pathway approach with low regrets, whilst being ambitious over the longer-term.

Meeting the Enhancement Criteria

Enhancement Criteria	
Need for Enhancement Investment	
Is there evidence that the proposed enhancement investment is required? (includes alignment agreed strategic planning framework or environmental programme where relevant)	The investment aligns with Defra's stated approach for AMP8, and supports DWI's and WHO's longer term objectives

Is the scale and timing of the investment fully justified, and for statutory deliverables is this validated by appropriate sources (for example in an agreed strategic planning framework)?	The AMP8 investment is appropriate to meet Defra's requirements and aligns with customers' preferences
Does the proposed enhancement investment or any part of it overlap with activities to be delivered through base, and where applicable does the company identify the scale of any implicit allowance?	We will continue to invest in base to meet the statutory requirements. Our enhancement investment is separate and positions for future changes in requirements and aligns with Defra's stated strategy
Does the need and/or proposed enhancement investment overlap or duplicate with activities already funded at previous price reviews?	This builds on and continues our development and understanding in how best to tackle lead pipe replacements
Is the need clearly identified in the context of a robust long-term delivery strategy within a defined adaptive pathway?	Defra has clearly stated the short-term requirements and DWI and WHO have set out longer term objectives
Where appropriate, is there evidence that customers support the need for investment (including both the scale and timing)?	Customer understanding and interest is relatively low, with generally a low-level of support for investment. Our AMP8 investment aligns with this
Is the investment driven by factors outside of management control? Is it clear that steps been taken to control costs and have potential cost savings (e.g. spend to save) been accounted for?	No
Best Option for Customers	
Has the company considered an appropriate range of options to meet the identified need?	A wide-range of options have been considered and economic analysis has been used to justify the preferred approach
Has a robust cost–benefit appraisal been undertaken to select the proposed option? There should be evidence that the proposed solution represents best value for customers, communities and the environment over the long term? Is third-party technical assurance of the analysis provided?	Our economic analysis approach has shown that lead pipe replacements are currently marginally cost beneficial. There are many uncertainties in the analysis. Our approach is to better understand the economics and reduce costs and to adjust future investment levels if and when they become more cost beneficial Our economic analysis approach has been assured by third-parties
In the best value analysis, has the company fully considered the carbon impact (operational and embedded), natural capital and other benefits that the options can deliver? Has it relied on robustly calculated and trackable benefits when proposing a best value option over a least cost one?	We have undertaken analysis of the impacts on embedded carbon and natural capital. The selection of our preferred option is not dependent upon the relative carbon and natural capital benefits
Is the impact (incremental improvement) of the proposed option on the identified need been quantified, including the impact on performance commitments where applicable?	Our economic assessment has considered the health benefits arising from the investments
Have the uncertainties relating to costs and benefit delivery been explored and mitigated? Have flexible, lower risk and modular solutions been assessed – including where forecast option utilisation will be low?	Many options have been considered and the uncertainties in costs and benefits explored in our preferred option selection Our economic analysis approach has been conservative by design to account for the inherent uncertainties in the analysis

Where appropriate, has the company secured appropriate third-party funding (proportionate to the third-party benefits) to deliver the project?	This is not applicable for this business case
Has the company appropriately considered the scheme to be delivered as Direct Procurement for Customers (DPC) where applicable?	This is not applicable for this business case
Where appropriate, have customer views informed the selection of the proposed solution, and have customers been provided sufficient information (including alternatives and its contribution to addressing the need) to have informed views?	We have engaged with customers and accounted for their views in our plans
Cost Efficiency	
Is it clear how the company has arrived at its option costs? Is there supporting evidence on the calculations and key assumptions used and why these are appropriate?	The majority of the cost forecasting for pipe renewal activities is based on either AMP6 or AMP7 actual delivery data. Costs are evidence based and so a high confidence grade would be considered for the data
Is there evidence that the cost estimates are efficient (for example using similar scheme outturn data, industry and/or external cost benchmarking)?	The costs derived for the options are based on the AMP6 and AMP7 costs. the disparate nature of the sites where activity is required limits our ability to drive efficiencies. Our trials in AMP8 will seek to find economies of scale from using street programmes and having a secondary purpose whilst undertaking the work
Does the company provide third-party assurance for the robustness of the cost estimates?	Please see the Costing & Investment Portfolio Optimisation appendix for more information
Customer Protection	
Are customers protected (via a price control deliverable or performance commitment) if the investment is cancelled, delayed or reduced in scope?	There is no protection for Lead as it does not meet materiality or aggregation requirements.
Does the protection cover all the benefits proposed to be delivered and funded (e.g. primary and wider benefits)?	There is no protection for Lead as it does not meet materiality or aggregation requirements.
Does the company provide an explanation for how third-party funding or delivery arrangements will work for relevant investments, including how customers are protected against third-party funding risks?	This is not applicable for this business case

Supporting Business Cases

- Lead Programme: Lead Programme.docx

Full Business Cases

Affinity Water

Water Network Resilience to Climate Change

July 2023

Contents

Summary

Our resilience ambition is to ensure that our customers' supplies are resilient in the long-term. Our water network faces increasing risks with one of the most significant being climate change driven extreme weather which is predicted to significantly increase the number of bursts on our water mains. The link between extreme weather events and mains bursts is well understood, with hot, dry periods or rapid temperature variations (e.g. freeze thaws) causing significant ground movement in clay soils that increases the mains bursts within the affected water networks.

We use a combination of techniques and investments to strengthen our resilience and to reduce bursts and leakage across the network. This spans both our base and our enhancement activities and integrates with our Network Strategy and our WRMP. Within base, we intend to ensure sustainable levels of asset health through effective capital maintenance and operational management. Our enhancement activities are focused on increasing our resilience to arising high-impact low-probability events, specifically those resulting from climate change.

We have consistently found that the provision of safe, secure, supply of water is a high priority for customers. When considering resilience in this context, customers' generally focus on reducing bursts and leakage. Bursts can have a significant impact on customer satisfaction as they can lead to disruption, traffic congestion and pollution. Reducing leakage is consistently mentioned in any engagement that we do, and always features in the upper quartile of priorities. As such, there is strong support for investing to address resilience issues, particularly by proactively reducing bursts and leakage through network calming initiatives such as pressure optimisation and real-time monitoring.

Listening to customers has informed our ambition for our network calming activity. This is to mitigate against climate change impacts by focussing on reducing bursts and leakage. This needs to appropriate, cost-efficient and part of a much longer, integrated strategy to protect supplies to customers.

Climate change is already increasing the frequency of such weather events. Our analysis indicates that climate change will increase the burst rate of our network by between 57 to 121 bursts per annum by 2050. This depends on the degree of climate change within the plausible range outlined within the Ofwat Common Reference Scenario (see figure 1 in our Network Calming LTDS Strategy). Unmitigated, these bursts will cause additional risk to the resilience of supplies, whilst repairs will create disruption for our communities and additional costs.

Our network calming plans have been developed, and optimised, as part of an integrated 25-year Network Strategy enabling optimisation of the whole set of network investments to maximise the benefits and ensure best overall value for customers. Our ambition for this investment therefore encompasses the delivery of these wider benefits such as leakage reduction. By investing in our network calming initiatives, we are creating an initial step change towards an optimised, innovative, and resilient water network in the face of current climate change scenarios.

We have identified an optimised programme of network calming over the period 2025-2030 that will mitigate the impacts of climate change in the most efficient way. The final enhancement Capex costs for AMP8 equates to £8.78m. The expected benefits from this investment by the end of AMP8 are: a reduction in bursts of 10.03; a reduction in leakage of 3.37Ml/d; and a reduction in interruptions to supply of 6.09%. Our economic analysis shows that these benefits provide a very strong cost benefit and justification for the investment.

This enhancement programme is designed to be delivered in alignment with the Base Network Calming Business Case, which has a Capex cost of £17.58 within AMP8. The Base Business Case is designed to deliver expected benefits by the end of AMP8 of a reduction in bursts of 73.43, a reduction in leakage of 5.23Ml/d and a reduction in interruptions to supply of 0.54%.

Overall, this investment has strong customer support; it is part of a wider and long-term strategy to provide on-going mitigation against climate change; and is highly cost beneficial providing best value for customers.

Project Details

AMP8 Spend	2025-26	2026-27	2027-28	2028-29	2029-30	Total
Capex (£m)	1.76	1.76	1.76	1.75	1.75	**8.78**
Opex (£m)	0.00	0.00	0.00	0.00	0.00	**0.00**
Totex (£m)	1.76	1.76	1.76	1.75	1.75	**8.78**
Drivers						
100%	Resilience					
Benefits						
Leakage (Ml/d) Water Supply Interruptions (property mins) Mains Repairs (number)						
Economic Analysis						
NPV Costs (£m) (2025-55)	**7.2**	NPV Benefits (£m) (2025-55)	**19.8**			
NPV (£m) (2025-55)	**12.6**	Benefit / Cost Ratio	**2.8**			

Six Capitals

Natural	Social	Financial	Manufact.	Human	Intellectual
	★ ★ ★	★	★ ★		★

Project Description

Our water network faces increasing risks of failure from extreme events. We have particularly identified that climate change driven weather events will significantly increase the number of bursts of our water mains. We therefore have an ambition to offset and mitigate this emerging risk by using network calming as part of a much wider integrated LTDS Network Strategy to strengthen the resilience of our asset base and to ensure the desired service to customers.

A range of network calming activities is able to help to mitigate the emerging risks:

Critical Valve and Smart Valve Ops Programme

Our Critical Valve and Smart Valve Operations Programme is designed to replace existing valves across the network with smart, actuated valves. Smart valves can be remotely operated, which reduces the durations of any interruptions to supply, over manual operated valves.

Watchkeeper Programme

Transients can be produced from pump and valve operations and in some circumstances can cause bursts across the network. Because our trunk mains generally distribute larger flows of water, it is sensible to focus effort to prevent bursts on our trunk main systems from these events, and therefore to reduce the risk of large leakage events.

Our Watchkeeper Programme will install 725 transients' loggers on our trunk mains. This equates to approximately one being installed every 2 km of trunk main. Adding these loggers will enable comprehensive network monitoring of the trunk mains. This will enhance our understanding and problem identification and enable much quicker response times to events.

Enhanced Pressure Management and Pressure Management Optimisation

Many of our customers are supplied via a PRV umbrella. This is a system with several inter-connected pressure reduction valves (PRVs) that are strategically placed throughout our water distribution network. These provide consistent and controlled pressure in the water distribution network, particularly in the trunk main systems.

Our Enhanced Pressure Management and Pressure Management Optimisation Programme focuses on further optimisation of our PRV (pressure reduce valve) umbrella systems. This will help us to optimise the balance between supply, demand, and hence system efficiency and to reduce bursts.

The programme will target the PRV umbrellas in our two largest hydraulic demand zones (HDZ) PRV umbrellas: Harrow and Harefield. The pressure management optimisation of these systems will reduce the frequency of bursts and the leakage caused by the bursts, whilst reducing the interruptions to supply of our customers.

Project Development

Baseline Assessment

Table 1 below shows a summary of our past performance against the common Performance Commitments: Mains Bursts, Per Capita Consumption, Leakage, Low Pressure, and Interruptions to Supply. This information was collated from our Annual Performance Review (APR) submissions.

PC	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23
Leakage (m3/km/day)	-	10.3	11.5	10.9	11.1	10.9	10.4	10.6	11.7	9.7	10.0	9.1	8.9
Leakage (l/property/day)	-	117.8	130.6	123.9	125.2	122.6	116.0	118.1	129.6	106.3	109.0	99.2	96.0
Leakage (Ml/d)	-	169.8	189.5	180.7	183.5	180.9	173.0	177.2	196.1	162.1	167.9	154.3	150.7
Low Pressure (No. Properties at risk of low pressure)	-	-	96	784	106	640	1101	2149	1954	5382	30311	24167	23680
Mains Bursts (Number per 1000 km of main)	-	173.8	131.6	136.5	145.5	132.5	185	175.2	151.5	125.4	158.9	100.2	169.6
Per Capita Consumption (l/head/day)	-	-	-	-	-	-	-	151.0	158.3	152.8	167.0	157.9	157.0
Water supply interruptions (Minutes)	-	17:50	19:28	22:42	27:03	17:55	21:07	32:54	12:43	13:36	05:49	03:43	12:53

Table 1: Past PC Performance

For most performance commitments, performance is either stable or has improved over the last 10 years. This has included performance step changes in Leakage, PCC, Mains Bursts, and Interruptions to Supply.

However, future projections for climate change indicate there is likely to be greater challenge to the resilience of the water network asset base, which could impact on the performance.

Problem Statement and Stated Need / Driver

The water industry is likely to be significantly impacted by climate change. OFWAT suggest that one of the main impacts of climate change is that "*changes in soil moisture levels may lead to changing patterns of pipe bursts and leaks*"[1].

Most water networks are constituted by pipes made from rigid materials such as Iron, cements, and rigid plastics (uPVC). As such they are susceptible to fracture if the

[1] OFWAT. (n.d.). *Climate Change*. Retrieved July 2023

ground around them moves beyond their ability to flex. Climate change is exacerbating the movements of the ground. Deeper soil moisture deficit in summers, prolonged high levels of deficit, rapid wetting and recovery of soils, deeper freeze, and rapid thaws all will be seen with climate change led to additional stress on the network.

The driver of the network calming activity is to offset and mitigate this emerging risk as the best value approach to protect our customers. The Network calming enhancement programme is part of an integrated 25-year asset strategy enabling optimisation of the investment to maximise additional benefit and ensure best value for customers. The scope proposed in AMP8 will lay the groundwork to mitigate climate change impact, focusing on innovative techniques beyond the conventional technologies we are deploying through base expenditure.

We have undertaken an analysis using burst data and average ground water level data by month from January 1990 to December 2019. Using this data, it is possible to observe a correlation between the increased variation in ground water levels and variation in bursts rates. There is measurable increase in the monthly burst rate delta and the monthly GWL (Ground Water Levels) delta. We have undertaken more granular work to better understand the reasons for these observations. The graphs in figures 1 to 3 display a trend of the average monthly burst rate (for condition driven failures only) and monthly delta change in GWL by month for each decade.

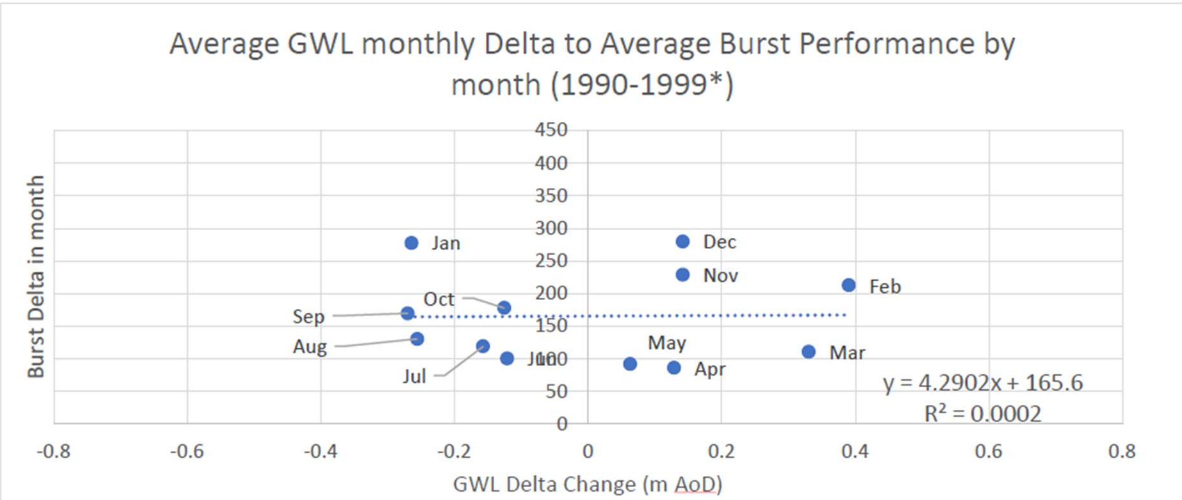

Figure 1 - 1990s GWL to Average Burst Correlation

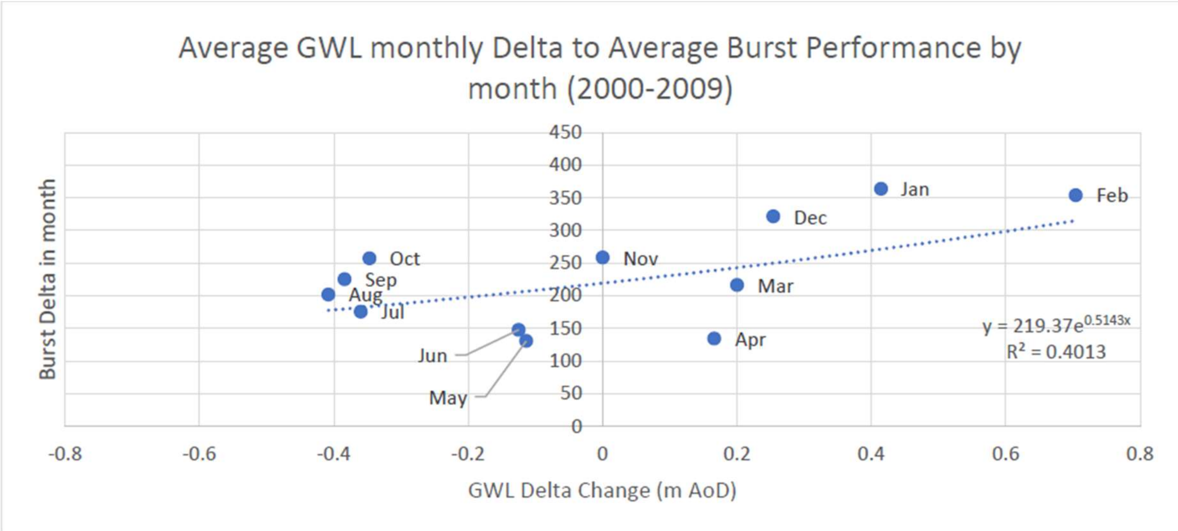

Figure 2 - 2000s GWL to Average Burst Correlation

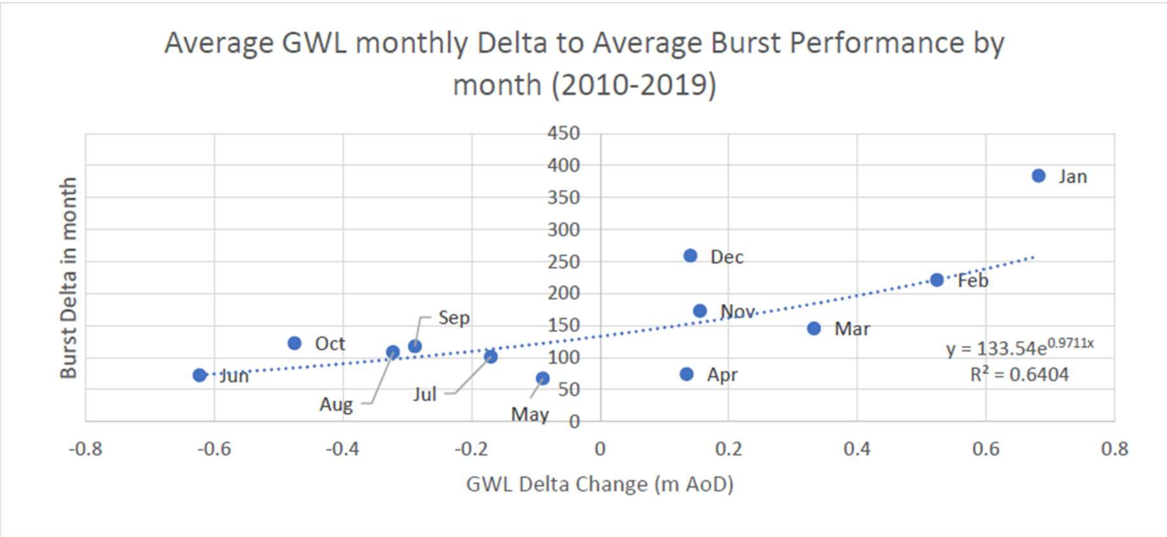

Figure 3 - 2010s GWL to Average Burst Correlation

It can be observed that whilst there is little correlation in the 1990's data set, the correlation is increasingly stronger across the subsequent decades. This appears to be due to consistently dryer periods in the summer months (negative changes in GWL) and more consistently wetter periods in winters (positive changes in GWL).

The Met Office report for UK climate 2022[2] stated: "*For the most recent decade (2013–2022) UK winters have been 10% wetter than 1991–2020 and 25% wetter than 1961–1990, with much smaller changes for spring, summer and autumn overall*", and "*The most recent decade (2013–2022) has been on average 0.3°C warmer than the 1991–2020 average and 1.1°C warmer than 1961–1990.*"

There is a measurable increase in the monthly burst rate delta and the monthly GWL delta. When the relationship is applied to the GWL sequence for the WRSE central scenario, the average mains bursts per annum increases over the 2025 to 2065 horizon, as shown in Figure 4:

[2] Met Office report "State of the UK Climate 2022"

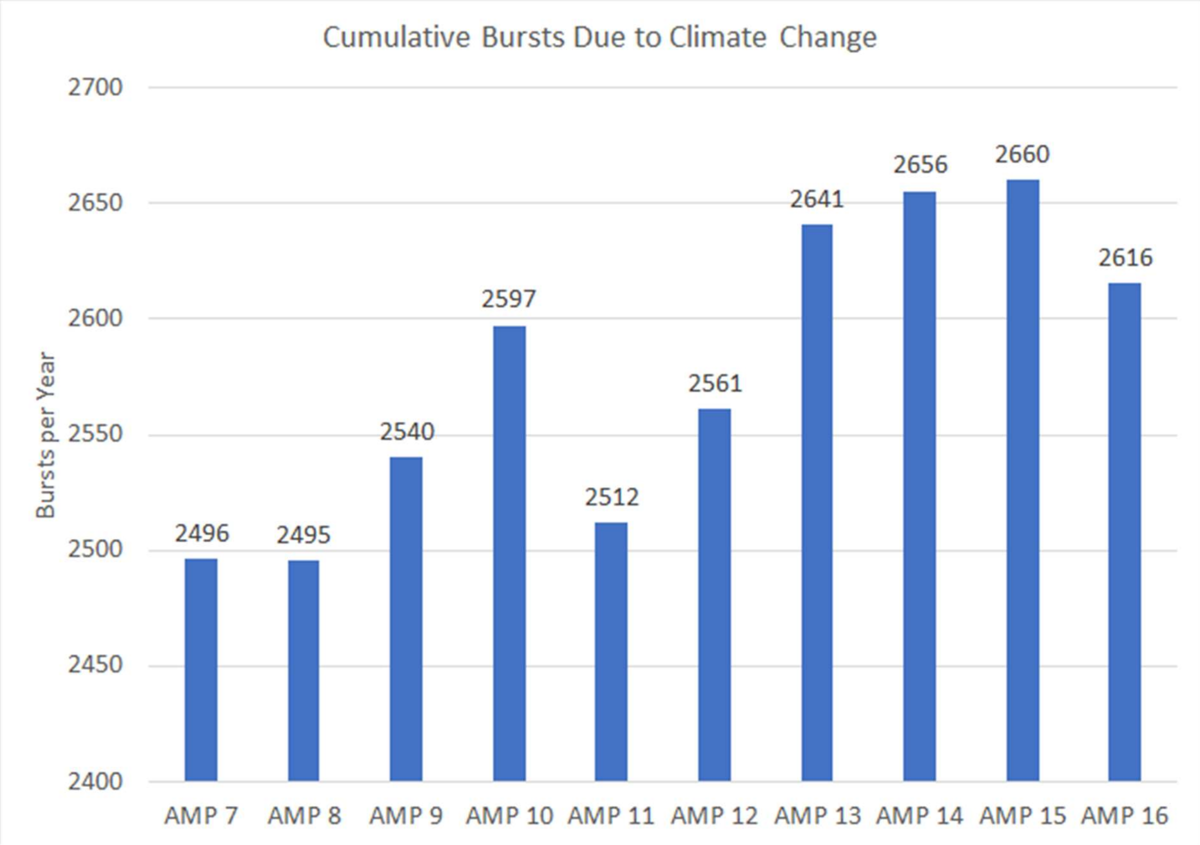

Figure 4 - Forward Projection of Average Annual Burst Rate Due to Climate Change

The results show that post AMP7, over the next 35-year period, climate change would account for an additional 160 bursts per annum beyond the end of AMP7. The variability from AMP-to-AMP (leading to decreases in AMP11 and 12) are a function of the probabilistic nature of the method used. The methodology uses ground water level data derived from the stochastic forward projection used in the WRMP. The main increasing trend remains across the time horizon.

Unmitigated, this will considerably impact the network, causing additional risk to resilience of supplies, whilst additional repairs will create further disruption for our communities, increase customer dissatisfaction, and add cost. Our ambition for this investment therefore encompasses the delivery of these wider secondary benefits such as leakage and interruption to supply reductions.

Allocation of Costs

For AMP8 the network calming interventions are set out below; split between base and enhancement Capex: Base = £17.58m and Enhancement = £8.78m.

The components of the Network Calming programme, including the Capex and the on-going Opex costs are shown in Table 2:

Programme	Base/ Enhancement	Component	Capex (£m)	Ongoing Opex Annual (£m)
Critical Valve & Smart Valve Ops Programme	Enhancement	Smart Valves for all DMA (District Metered Areas) boundary Valves	£2.25	£0
Watchkeeper Programme	Enhancement	Permanent Trunk Main Transient Monitoring	£2.18	£0
Enhanced Pressure Management	Enhancement	Pressure Management Optimisation	£4.36	£0
		Enhancement Total	£8.78	
Enhanced Pressure Management	Base	New PRVs (Pressure Reducing Valve) and Controllers	£14.58	£0.29
Digital Integration	Base	OT/IT integration	£3.01	£0.06
		Base Total	£17.58	

Table 2 - Components of the Network Calming Programme

Our enhancement activity will increase our asset systems' resilience to high-impact low-probability events, whilst our base programme will maximise the potential use of conventional technologies such as standard pressure reducing valves (PRVs). The base programme will be fully delivered in AMP8 as well and will help to ensure sustainable levels of asset health along with our main renewals base programme, forming an integral part of our integrated 25-year asset strategy.

Direct Procurement for Customers

Direct Procurement for Customers (DPC) is a financing model designed for larger water infrastructure projects, allowing them to secure competitive financing. Water companies consider DPC for relevant projects by running a competitive tender to appoint a third party known as a competitively appointed provider (CAP) for designing, building, financing, operating, and maintaining new infrastructure. DPC fosters competition, encouraging innovation, and investment, leading to improved outcomes for customers. It promotes accountability among water companies and delivery partners to meet high standards of performance and efficiency for strategic water resource delivery. DPC is supported when it demonstrates value for customers and the environment. For PR24, Ofwat applies DPC by default to discrete projects above a £200m threshold.

We have thoroughly assessed the scheme's suitability for a Direct Procurement for Customers approach, and based on our evaluation, it does not meet the criteria due to its value falling significantly below the £200m Totex threshold. This decision is in accordance with the details provided in our DPC Appendix document[3], where we have developed an eligibility framework, derived from Ofwat's guidance to screen investments using a consistent and evidence-based approach with potential to meet the conditions for DPC. We established a set of eligibility criteria designed around Ofwat's three tests (Programme Scalability Test, Construction Risk Test and Operations & Maintenance Risk Test), while also considering including whole life cost, technical discreteness, and value for money. We also considered if there were any mitigating actions to take to ensure the integrity of our system resilience to protect services to customers in the event a DPC scheme has system resilience risks.

Research, Pilots, and Technology Development

Technological advances have already demonstrated their ability to alleviate the significant network investment that would otherwise be required. To empower full benefits of network calming within the base and enhancement business cases, there are key enablers in the form of technology deployments within Network calming programme, smart valves (enhancement) and digital integration (base) components.

In alignment with the network calming enhancement business case, we will seek innovation funding to lead on innovative technologies trial within the network. We will conduct research into innovative techniques and technologies trials, that will help us on the journey to have an optimised and automated network, increasing network visibility real time and the quality of our data. Following the completion of these trials the components will be evaluated. Where proved to be cost beneficial, and part of the best value solution, this will be deployed on a larger scale over later periods.

Additionally, Affinity Water is sponsor of OFWAT innovation project, Safe Smart System project[4] led by Anglian Water. This project focuses on embedding long term operational resilience in next generation water systems and taking the first steps to achieve autonomous control. It aims to transform how we use and process data, operate our system and make better and optimised decisions with the use of an AI Decision Engine. This will enable real time processing of data, scenario optimisation and making/actioning operational decisions. The increased automation will help better prediction and management of disruptions, leading to a more effective level of service to our customers and enhanced protection of the environment.

By harnessing the power and learnings from the Safe Smart System project's technologies and predictive capabilities, our intention is to take cutting edge approaches to network calming, discovering more efficient, less disruptive and/or more deliverable approaches.

[3] PR24 DPC Appendix

[4] Safe Smart System Project

Customer Engagement

We have compiled all our customer research and analysis into a comprehensive document titled 'What our Customers & Stakeholders Want (WCSW)'[5]. This document presents the outcomes derived from numerous customer engagement activities, ensuring that our plans and strategies deliver what our customers want, considering their needs and expectations.

Customer Engagement Activities

We have undertaken extensive engagement with our customers to build a detailed understanding of their priorities and reflected these in this business case. For more detail on our customer engagement see AFW04 What Customers and Stakeholders Want.

The insight and testing of our business plan with customers have been integral to its development. The voice of the customer is used throughout to shape and challenge the plan across its development.

The triangulated customer insight has shaped and informed the overall strategy, informing each business case and the solution options within them. The triangulated customer valuations have populated the Service Measures Framework used to prioritise investments.

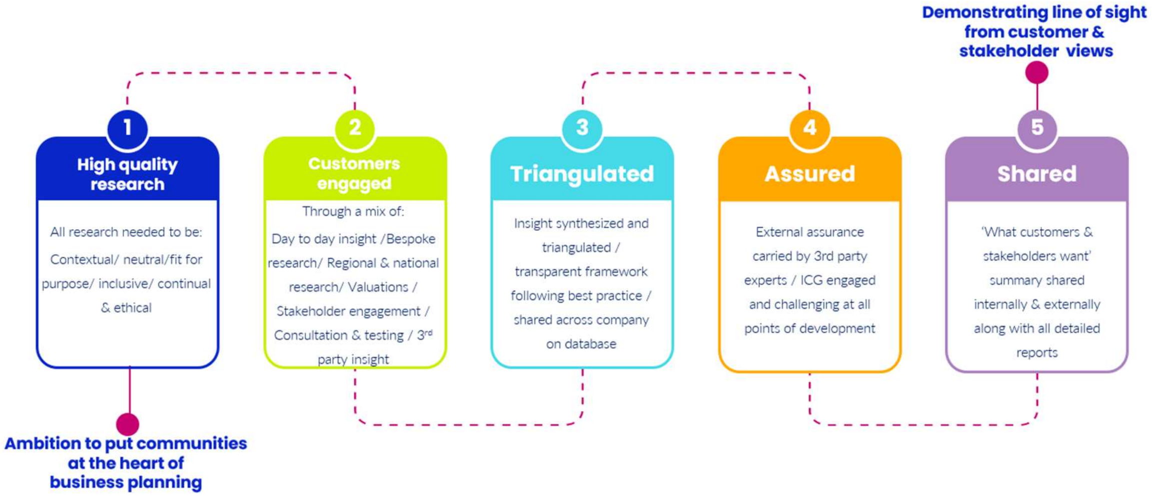

Figure 5 – Customer Engagement Process

The consultation and testing phases of engagement allowed us to 'check-back' with customers and stakeholders to ensure overall acceptability and affordability of the plan. We have shared our assured findings both across the business and publicly to ensure transparency.

[5] 'What our Customers and Stakeholders Want' report version 5 – See Appendix 1

Evidence of Customer Preferences

We have run qualitative research, conducted by Impact Research LTD, which looked at three areas – Water Quality, the Environment and Resilience. The qualitative research approach consisted of focus groups and in-depth interviews. A total of 48 participants were invited to attend the focus groups, supplemented by an additional 6 in-depth interviews lasting up to 45 minutes conducted over the telephone.

Figure 6 - Quality research approach

Participants were invited to attend specific sessions based on their demographic profile where we asked our customers where they think that we should focus its attention. Reducing leakage was amongst their key priorities. It is an area that is regularly mentioned in any research or engagement we do, and in our priority engagement across all the insight we see leakage consistently featuring in the top quarter of priorities (WCSW pg. 8). Leaks are also a popular reason for contact from customers and there is evidence that those who do contact about a leak are generally more dissatisfied with our service in comparison to other areas (WCSW pg.32).

Another top priority outcome of the research was to provide a safe, secure supply of water and particularly noted by non-household customers. (WCSW pg. 8&9). Bursts are one of the areas our customers do identify when they think about resilience (WCSW pg. 29). Bursts can have a significant impact on customer satisfaction and various aspects of society, leading to disruption, traffic congestion and pollution.

Therefore, all the above underlines that our customers support greater leakage reduction and improved resilience. By proactively reducing bursts and leakage with network calming initiatives such as pressure optimisation and real-time monitoring, the interventions outlined in this business case will have positive long-term impacts for both.

Customer Protection

Customers are protected via the proposed Price Control Deliverable (PCD) metric which is based on the additional number of customers protected from climate change impact in burst, leakage, and interruption to supply.

The measurement of this PCD will be based on the reduction of the risk of bursts, leakage and significant interruptions to supply resulting from severe weather events.

The customer protection covers primary, and some wider benefits, as it reduces interruptions to supply events, leakage, and bursts. It is essential however to acknowledge that certain intangible benefits, such as impact on traffic disruption and the satisfaction of specific customers affected either by the traffic or those who will not experience interruptions, will not be measured.

For this programme third-party funding is not applicable. As mentioned in DPC section, this scheme is not suitable to be considered for a Direct Procurement for Customers approach. We will fund this programme based on a unit cost allowance from our Resilience driver, based on a leakage reduction to be mitigated by 31 March 2030. If the company does not deliver the maximum leakage reduction, we will calculate any cost sharing based on a proportioned 'target cost'. For more details, please refer to Appendix 7 to our Price Control Deliverable Resilience report.

Partnering

Collaboration and Partnering

Engagement with Stakeholders and Partners

This business case was developed as part of the Network Strategy and was influenced by work completed by PA Consulting that utilised their knowledge of similar approaches across the industry. Throughout the strategy development, internal stakeholders were engaged ensuring appropriate governance and ownership. A two-stage governance process was agreed based on a regular cadence of meetings over the 3-month programme comprising a Working Group (the job roles of the attendees can be found in Appendix 4) met on week 3 of every month and a Steering Group meeting in week 4, this was also supported by ad-hoc Subject Matter Expert (SME) challenge sessions.

Once the Network Strategy development was completed, the network calming investments and benefits have been scrutinised by relevant stakeholders and SMEs during deep dive sessions where network operations, customer delivery, operations control room, leakage operations and customer experience departments met to review and challenge network related programmes. This ensured strategic focus and direction. Following these reviews, elements of the network calming business case adjusted appropriately. Outcomes of this process have been to calibrate the original approach to our asset base and validate the costs and benefits. This has had the effect of reducing the investment requirements from the original PA proposed plan and reducing the uncertainty in the benefits to be derived from the approach.

Co-design and Co-delivery

To ensure the success of the Network Calming Programme, network deliverability workshops were held engaging key stakeholders: Control Room; Asset Planning; Supply Chain; Leakage Operations; and Customer Delivery teams.

The design of the three components of this programme (Enhanced Pressure Management, Watchkeeper programme and Critical Valve and Smart Valve Ops) will be carried out by our in-house teams. The construction phase will be delivered through NIMA2 (Network Infrastructure Maintenance and Repair contract), which will be tendered through a new individual contract for AMP8 where our current NIMA2 partners can bid. Our in-house Construction Management team will oversee the construction, and commissioning will also be facilitated by our internal teams.

We also undertook a Business Capability Matrix assessment tailored to this programme. Its results will play a key role in ensuring our ability to fulfil and execute this programme successfully.

Strategy Development

All of our enhancement cases have been developed as part of our integrated investment portfolio that takes the first steps of our Long Term Delivery Strategy and achieving our ambitions as laid out in AFW03 Strategic Direction Statement.

Long-term Delivery Strategy Alignment

In our Strategic Direction Statement[6] we commit to "*Be prepared for change, and resilient to shocks and stresses*". We also commit to "*Ensure a resilient supply of water for Affinity Water customers*" and to "*Ensure our physical assets are resilient for the long-term*". We are already delivering on these commitments by actively addressing the challenges posed by climate change impact on our water network where no other management of the risk is possible without the detrimental effect on the resilience of the network.

This programme aligns to our WRMP and Network Strategy, as an integral component of our 25-year asset strategy. The investments proposed within this business case are aligned with the Core Adaptive Pathway of our LTDS and will not adversely impact any of the potential Alternate Pathways identified within the LTDS. These investments will still be required under all common reference future scenarios and are pivotal to our ability to fulfil our Performance commitment over the long-term. Disrupting this synergy could jeopardise the effectiveness of our long-term commitments and strategic initiatives, increasing risks and impeding the ability to provide a reliable and uninterrupted service to customers.

Network Strategy

There are many challenges facing our network ranging from the behaviour of customers, deteriorating asset base and climate change etc. Our Network Strategy has been designed to overcome these challenges throughout AMP8 and over a 30-year horizon. Through the development of this strategy, we are able to optimise investments; meet a number of services requirements and provide improved service for our customers over the short, medium and long-term. To develop the strategy an understanding of the following was considered:

- Understanding the company's strategic ambition including common performance commitment level ambitions to 2050
- Understanding long-term impacts of existing programmes such as Supply 2040 and Connect 2050
- Emerging reference scenarios published by Ofwat
- Current deterioration projections for the asset base

Adaptive Strategy

[6] AW0031 Strategic-direction-statement report – See Appendix 2

The Network Strategy and the network calming business case consider the following uncertainties and need for adaption (aligning to the LTDS):

- Climate Change – difference between low emission (RCP2.6) and high emission (RCP8.5) climate change scenarios in WRMP (Water Resource Management Plan)
- Benefits range for calm networks – low/medium/high
- Growth – linked to WRMP and ONS ranges
- Demand Management – assumptions of success in reducing PCC without economic measures (e.g., tariffs)
- An approach less sensitive to technology – current calming assumptions are based on established technologies and maybe able to move faster (higher calming scenario)

Reviews will be held at the end of each period (prior to the relevant price review and aligned to strategic frameworks like WRMP) using the model below within Figure 8:

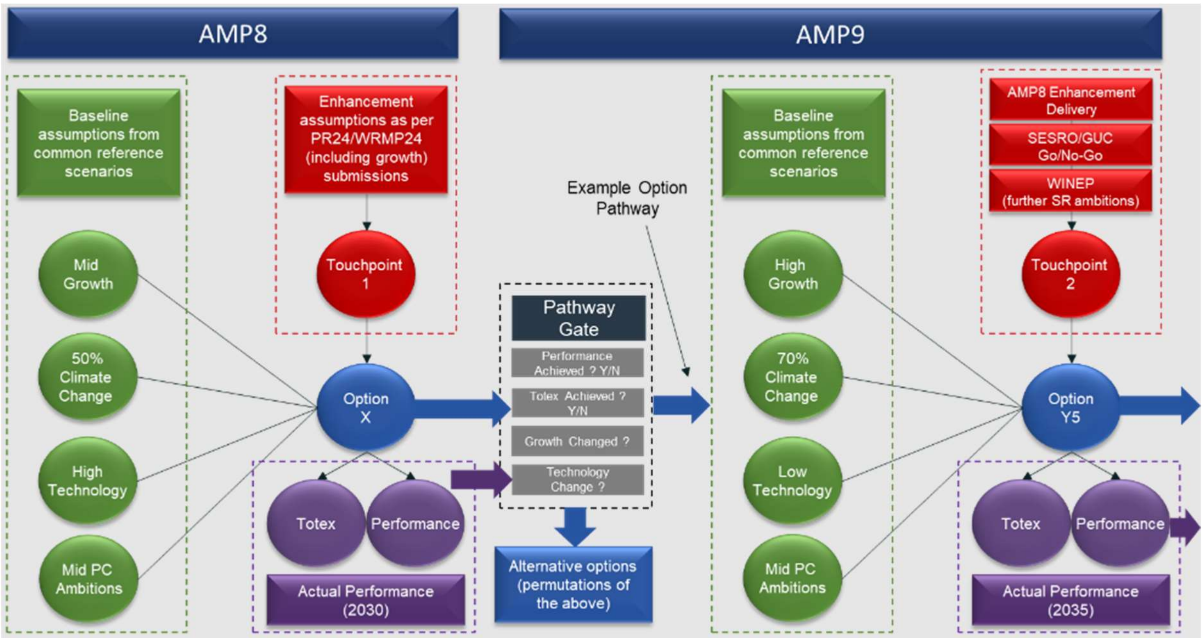

Figure 8 - Mechanics of Changing Pathway

Optioneering

We have consistently proposed best value solutions using rigorous optioneering. For more detail on our approach is provided within AFW08 Our Investment Development Process.

The network calming business case has been developed as an integral part of our long-term Network Strategy (see Appendix 3), and it plays a crucial role in our capacity to meet our Performance commitment over the long-term. We developed and selected the network calming activities during the strategy development through rigorous optioneering process using PIONEER, our asset management system tool. This process involved multiple phases of development, including modelling various options, which shaped the network strategy and this business case.

The Network Strategy was developed in two phases:

Phase 1 – Initial Optioneering and Modelling

Phase 1 was focused on defining the strategic ambitions out to 2050, in alignment with those already set out in Connect 2050 and other long-term strategy documents. This enabled us to present a suite of strategic network options to the board in April 2022, supported by an additional model of Botex interventions and Ofwat reference scenarios out to 2050.

Stated Ambitions

Table 3 summaries the commitment levels agreed upon during Phase 1. These commitments served as the foundation for our "stated ambition" options, providing insight into Affinity Water's relative position within the industry, categorised as follows:

- Q1: Upper Quartile
- Q2: Median – Upper Quartile
- Q3: Median – Lower Quartile
- Q4: Lower Quartile

PC (Performance Commitment)	AMP6	AMP7	AMP8	AMP9	AMP10	AMP11	AMP12
Water supply interruptions (Minutes)	6	3	2.2	2	2	2	2
Water supply interruptions (Minutes)	Q1	Q1	Q1	Q1	Q2	Q2	Q3
Mains Bursts (Number per 1000 km of main)	180	145	145	145	145	145	145
Mains Bursts (Number per 1000 km of main)	Q4	Q4	Q4	Q4	Q4	Q4	Q4
CRI (Compliance Risk Index) Score (Index) *(Current industry targets = 0)*	3.2	0	0	0	0	0	0
CRI Score (Index) (Alternative Projection)	-	0.84	0.46	0.25	0.14	0.08	0.04

CRI Score (Index) (Alternative Projection)	Q3	Q2	Q2	Q2	Q2	Q2	Q2
Per Capita Consumption(L/head/day)	146	129	123	117	110	110	110
Per Capita Consumption(L/head/day)	Q4	Q4	Q2	Q2	Q1	Q1	Q2
Leakage(m3/km/day)	9.4	8.0	7.2	6.6	6.1	6.0	5.2
Leakage(m3/km/day)	Q4	Q4	Q4	Q4	Q4	Q4	Q4
Leakage(L/property/day)	102	87	78	72	66	65	57
Leakage(L/property/day)	Q3	Q3	Q3	Q3	Q3	Q3	Q4
Low Pressure (% Properties at risk of low pressure)	0.016%	0.011%	0.006%	0.001%	0%	0%	0%
Low Pressure (No. Properties at risk of low pressure)	261	178	94	10	0	0	0
Low Pressure (Properties at risk of low pressure)	Q4	Q4	Q4	Q2	Q1	Q1	Q1
Water Quality Contacts (Number of contacts per 1,000 population)	-	0.67	0.67	0.67	0.67	0.67	0.67
Water Quality Contacts (Number of contacts per 1,000 population)	-	Q2	Q2	Q2	Q2	Q3	Q4
Water Quality Contacts (Number of contacts per 1,000 population) (Alternative Projection)	-	0.67	0.51	0.35	0.20	0.16	0.01
Water Quality Contacts (Number of contacts per 1,000 population) (Alternative Projection)	-	Q2	Q2	Q1	Q1	Q1	Q2

Table 3 - Stated Performance Ambitions

Modelling

We conducted comprehensive modelling to optimise our interventions and align them with our PR24 ambitions while considering the long-term perspective. This came through the refinement of our existing PIONEER datasets. PIONEER was used to perform portfolio optimisation, which determines interventions based on the current asset base and up-to-date costs data.

In the initial phase, we focused on high-level modelling using a layered approach. This phase was divided into distinct workstreams, including:

- **Performance assessment:** We evaluated expected industry performance over the period 2025 to 2050 based on data from Ofwat and other water companies. This helped determine our position relative to the industry and develop alternative trajectories to meet specific ambitions.

- **Climate Scenarios Analysis:** Our deterioration and investments models were used to evaluate various climate scenarios against different performance levels and Botex investment requirements. We also reviewed these scenarios considering Ofwat's adaptive planning guidelines outlined in its LTDS guidance.
- **Disruptors Impact Assessment:** We studied the impact of disruptors such as smart networks on the above scenarios. This involved revising investment profiles to illustrate the benefits of adopting selected technologies, both in terms of total cost and the potential for smoothing investment profiles.

- **Asset classes considered:** We conducted the analyses for various asset classes within the water network.
    - Strategic Networks (Transmission and Trunk Mains)
    - Service Reservoirs
    - Booster Stations
    - Distribution Mains
    - Communication Pipes
    - Sensors and Metering
- **Stakeholder engagement:** We engaged with stakeholders through workshops to validate and challenge our assumptions and outcomes.

Options Development

From this process, we generated 60 option permutations. Through consideration of the stated ambitions this concluded with four options: a baseline "do nothing" scenario and three selected options based on cost, performance, and feasibility.

The four selected options met the Totex and performance ambitions of the steering group and were approved for further development during Phase 2. These options are highlighted below in Table 3:

Option	PCL	Weather Scenario	Calming Scenario	Enhancement Scenario
Option 1	Stable	Historic Weather	Network Calming Excluded	Mandatory[7] Only
Option 15	Stated Ambition	Historic Weather	Network Calming Included	Mandatory + Likely SI[8] + Further Ambitions[9]
Option 19	Stated Ambition	Historic Weather	Network Calming Included	Mandatory Only

[7] Mandatory enhancement consists of scope which Affinity Water is already committed to through WRMP, WINEP programmes, and an additional allowance for raw water deterioration.
[8] "Likely SI" constitutes strategic resource options such as the Grand union canal, southeast strategic reservoir, and their associated development costs. At the time of the development of phase 1, these are not fully defined and so the latest RAPID submissions have been used to attribute a cost split between partnering utilities.
[9] "Further ambitions" relate to investment targeting emerging water quality risks, and continued investment in lead pipe replacements at a rate currently above the rest of the industry.

Option 23	Stated Ambition	Historic Weather	Network Calming Included	Mandatory + Likely SI

Table 4 - Selected Options: Phase 1 Summary

Impact of Network Calming

As part of this strategy development, we considered potential disruptors to long-term performance. One of the technological disruptors identified is calm networks, which likely forms part of the smart network future outlined in Ofwat's common reference scenarios for the low and high technology pathways.

Phase 1 results:

- Approximately 24% and 41% of mains failure are likely have a transient-driven failure mode, reducible by network calming activities.
- We assessed the Totex cost of implementing network calming over AMP8 and AMP9.
- The conclusion is that even when making a conservative assumption of a 12% reduction in failures over 10 years, there is a minimum potential saving of £100m in Botex by 2050

These findings recommended a full business case for Network Calming in Phase 2 of the Network Strategy.

Phase 2 – Refinement of the Options

The aim of this phase was to develop a mature Network Strategy by November 2022. This strategy considered cost, performance, and risk factors, aligned with our needs across this period, including base and enhancement interventions, and Ofwat's reference scenarios.

From the initial four options, we narrowed it down to a final solution through agreement at steering groups. We assessed the options based on cost, complexity, and feasibility. Phase 2 led us to a single preferred long-term Network Strategy with adaptive pathways, ensuring flexibility to incorporate emerging technologies and changes in the regulatory landscape.

Phase 2.1 – Option Selection

Option selection for this phase involved three key steps:

Refinement of Selected Options

The options listed in Table 4 underwent further refinement through remodelling of costs and benefits. Major changes since Phase 1 included the impact of network calming on reducing required investments such as main renewals, as well as adjustments to enhancement scopes.

Option profiles were then developed to understand the investment outlook over a 30-year period. No updates were made to stated ambitions in this phase.

1. Refinement of Network Calming Assumptions

In Phase 1, we estimated a net benefit range of approximately £100m to £280m for calm networks from 2025 to 2050, assuming a Totex of £38m over AMP8 and AMP 9.

In Phase 2, the underlying assumptions were updated based on emerging intelligence from the rest of the industry, where network calming programme benefits are now being observed. This included a more detailed analysis of the impact of delivering the program in a single AMP (AMP8).

The result of this reassessment indicated that delivering the program in AMP8 with a Totex cost of £51.5m could achieve long-term Network Strategy ambitions for approximately £498m less than traditional approaches over 25-year period. In AMP8, network calming resulted in reduced mains renewal programme, reduction in bursts, interruptions to supply, and leakage, along with an improved CRI.

Based on this enhanced assessment, it was recommended that Calm Networks be developed further into a business case, inclusive of assessment of benefits across multiple ODIs.

2. Updated Scorecard and Preferred Option

Out of the 4 Options chosen in Phase 1, Option 19 was selected option for progression to Phase 2.2, delivering the long-term performance ambitions at a similar Totex cost whilst maintaining stable serviceability. This is achieved by fully leveraging Network Calming in AMP8 and maximising the benefit of the enhancement investments on existing infrastructure.

This decision was made after discarding Option 1 for not meeting service requirements and Option 23 for providing no additional benefits over Option 19 at a higher Totex. Options 15 and 19 were similar, with Option 15 having a lower Totex but containing elements requiring further internal sign-off.

The specific configuration of the selected option is provided below within Table 5:

Option	25-Year Totex (£m)	Totex Delta (£m)	Totex Rank	Leakage	Bursts	Interruptions	CRI	WQ Contacts	Pressure
Option 1	£3,249	£0	2	Fail	Fail	Fail	Fail	Fail	Fail
Option 15	£2,969	-£280	1	Pass	Pass	Pass	Partial	Pass	Pass
Option 19	£3,363	£114	3	Pass	Pass	Fail	Partial	Pass	Pass
Option 23	£3,805	£556	4	Pass	Pass	Fail	Patrial	Pass	Pass

Table 5 - Selected Options during Phase 2.1

The specific configuration of the selected option is provided below within Table 6:

Option	Performance Commitment Level	Weather Scenario	Calming Scenario	Enhancement Scenario

Option 19	Stated Ambition	Historic Weather	Network Calming Included	Mandatory Only

Table 6 - Final Selected Option from Phase 2.1

Phase 2.2 – Refinement and Detail of Preferred Option

During Phase 2.2, we updated the investment models using the updated PIONEER databases. This allowed us to create detailed investment profiles for Option 19. We assessed Option 19 against four performance scenarios, including stable performance, stated ambitions and upper quartile performance,

We reviewed the "no regrets" treatment options by combining deterioration modelling data with timelines for major enhancement programmes, and we developed an approach to climate change and weather modelling based on WRSE Central Scenario data and our updated ground water data.

Throughout this stage, we engaged with internal stakeholders to ensure coordination with other strategic plans and current thinking.

Deterioration Modelling – Refinement with latest data

To create a detailed investment profile for the selected option (Option 19), we used PIONEER modelling to carry out six distinct scenarios, each with a varying level of network performance, as shown below in Table 7:

Scenario	Descriptions
1	Baseline – Stable Performance
2	Stated Ambition
3	Stated Ambition -10%
4	Stated Ambition + 10%
5	Upper Quartile Performance
6	Non-Infrastructure Baseline *

Table 7 - 6 Scenarios for PIONEER Modelling

*Used to test treatment costs, and isn't directly comparable with the other scenarios

From this modelling, it was possible to compare the required level of investment across each of the scenarios, shown below in Figure 7

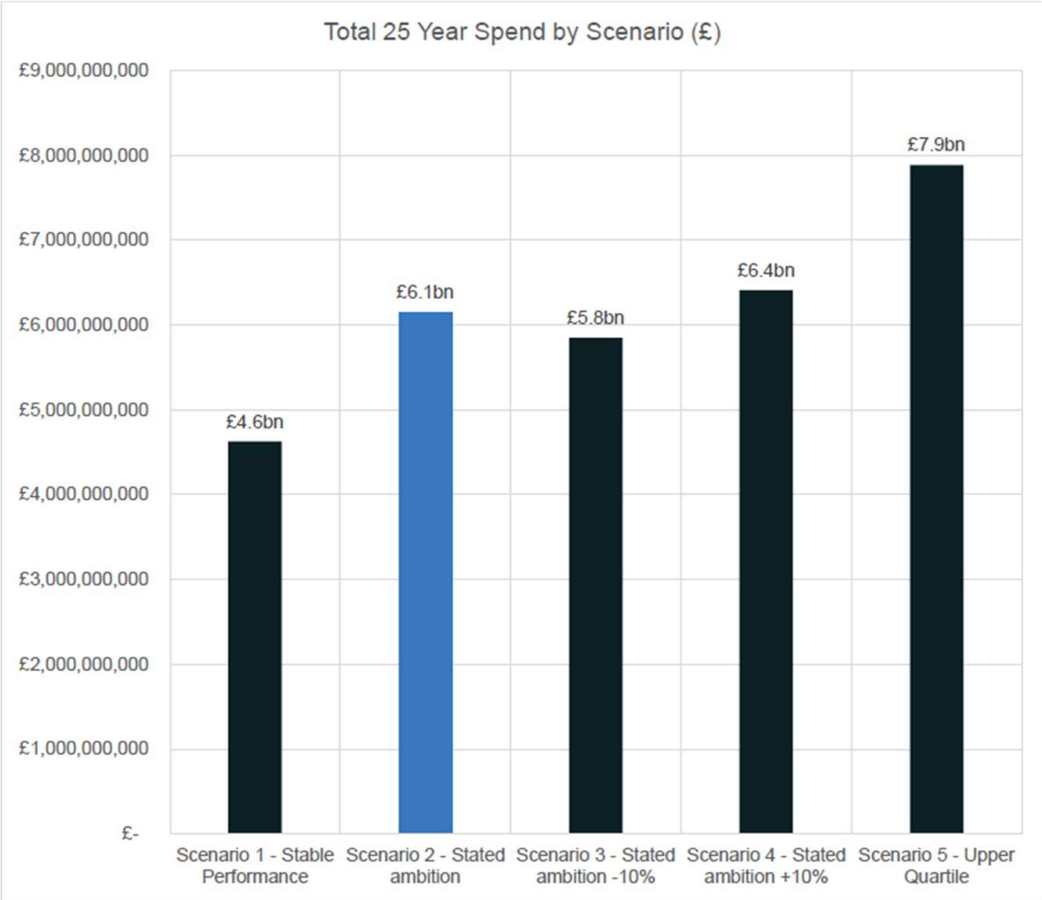

Figure 7 - Scenario Totex Comparison

What can be observed is the significant amount of investment that would be required to achieve upper quartile performance – this was excluding the additional cost implications of climate change (which was estimated to add a further £300m of mains renewals).

Climate Change Impact Methodology– Modelling Refinement with the Final WRMP Data

Building on the climate change impact to asset health insights from Phase 1 and Phase 2.1, PA Consulting designed an approach that was utilised by in-house modellers. This approach assesses the impact of weather and climate change on network performance, with a focus on a granular review based on historical correlation.

The first step of the approach is outlined below in more detail:

1. Plot bursts by failure mode for chosen historical period (from 1990 to 2021) based on our data sets (from PIONEER system and pipe lab database).
2. Plot Ground Water Levels (GWL) monthly averages from 1990 to 2021 for selected observation borehole sites. In this test case, Lilley Bottom borehole was chosen as representative of our Central Area (provided by the Water Resources team).
3. Remove all other non-condition failure modes from the burst failure monthly figures from 1990 to 2021.

4. Calculate the average monthly condition-based burst by month and split by average over chosen historical period (1990 to 2021) / by decade and any desired sub-set (e.g., 5 yearly). Note, for the purposes of this initial assessment a monthly average by decade was used to observe long-term changes.
5. Calculate the average monthly GWL by month and split by average over chosen historical period (1990 to 2021) / by decade and any desired sub-set (e.g., 5 yearly).

Note, for the purposes of this initial assessment a monthly average by decade was used to observe long-term changes.

6. Calculate the average monthly rate of change for GWL for the chosen period. In this assessment decadal average rates of change were used – e.g., rate of change from 1990s January to 1990s February.
7. Plot the average monthly burst rate in each period to the GWL rate of change in the same period. In this assessment, this was the average GWL rate of change for a given decade e.g., 1990s January to 1990s February plotted against the average burst rate in each month in the 1990s.
8. Plot trend-line for the given time periods and compare changes in R2 value over those time periods (in this case the 1990s, 2000s and 2010s).
9. Take equation from the latest period to test with projected groundwater levels from WRMP stochastic modelling outputs for the given climate change scenario. Review outputs of the test (recommend using central WRMP scenario) in terms of predicted burst rate for 2025 to 2070 and undertake further sensitivity testing.

Using the results from stages 1-3, it was possible to observe a correlation between the increased variation in ground water levels across an average year and variation in bursts rates. The results also showed a measurable increase in the monthly burst rate delta and the monthly GWL delta over three decades – this suggests a higher volatility in observed weather events leading to higher burst rates if unaddressed.

Following the completion of stages 4-8, it was observed that whilst there is little correlation in the 1990s data set, the higher R2 number indicates that there is an increasingly strong correlation in the 2000s and the 2010s, with a measurable increase in the monthly burst rate delta and the monthly GWL delta.

Using this relationship, stage 9, we applied it to the projected groundwater models of our central area until 2070, which were derived from the stochastic modelling used in the WRMP. The results from the analysis on the effects of Climate Change shows that over a 35-year period, climate change would account for an additional 160 bursts. The graph shows that, although the frequency of bursts increases over a long period, the frequency of bursts has a high variability from AMP-to-AMP. This is shown below, in Figure 8:

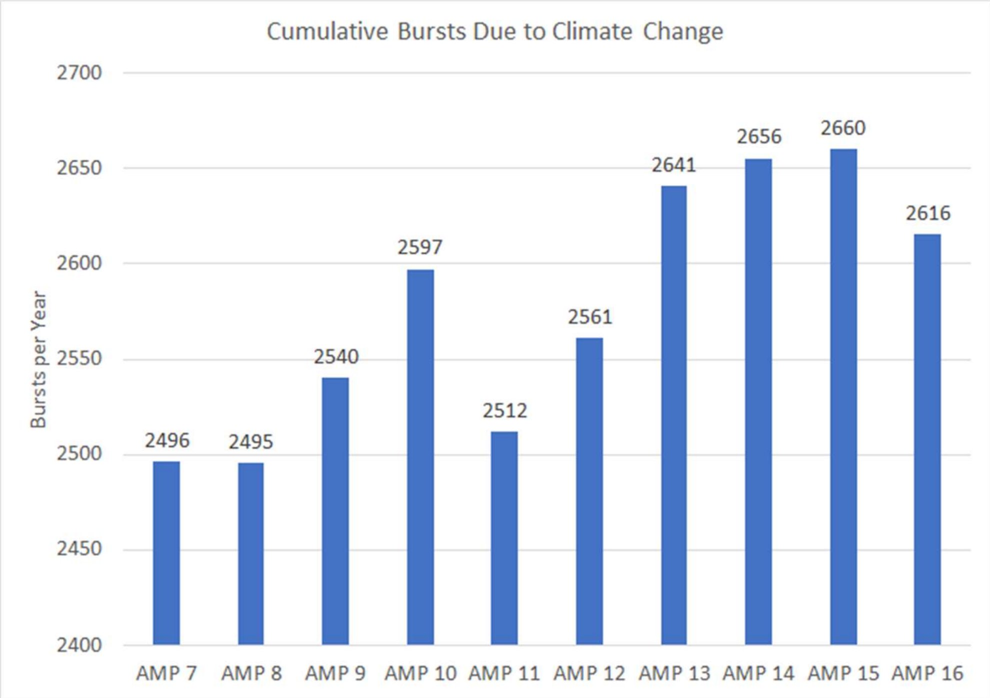

Figure 8 - Forward Projection of Average Annual Burst Rate due to Climate Change

This variability from AMP-to-AMP periods is due to the method that we investigated the effects of climate change. The methodology uses a stochastic forward projection for the groundwater levels of one of our boreholes, to derive a frequency of bursts per year.

The exact profile that climate change is expected to affect frequency of bursts within the network is unknown. Due to this uncertainty and to prevent lumpy Capex, we have evenly distributed the 160-burst difference between the end of AMP 7 and AMP 14 to avoid irregular capital expenditures. See **Error! Reference source not found.** below.

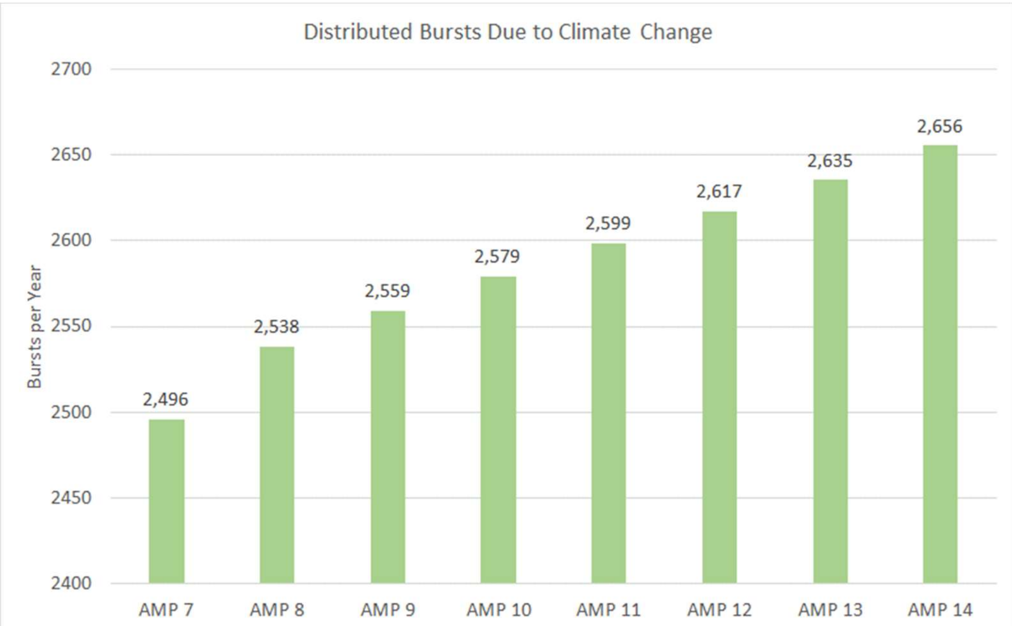

Figure 9 - Distributed projection of average annual burst rate due to Climate Change

This smoothed version of the profile, shown in Figure 9, has been used for designing solutions and long-term spend due to the higher deliverability. The implication of the above is that renewal rate would need to increase from 1070km (no climate change) to 1214km (with climate change) per AMP by 2055 to meet our stated ambition.

The results shown above reflect the adverse RCP 8.5 scenario (high emission scenario). This is due to the stochastic datasets, used in this analysis, are a projection of the RCP 8.5 scenario. To assess the effect of the benign RCP 2.6 scenario (low emission scenario), we applied a scaling factor following Atkins's guidance in the WRSE Climate Data Tools Scaling Report[10]. The results of this scaling, showing only the additional bursts attributed to climate change, are presented in **Error! Reference source not found.** below:

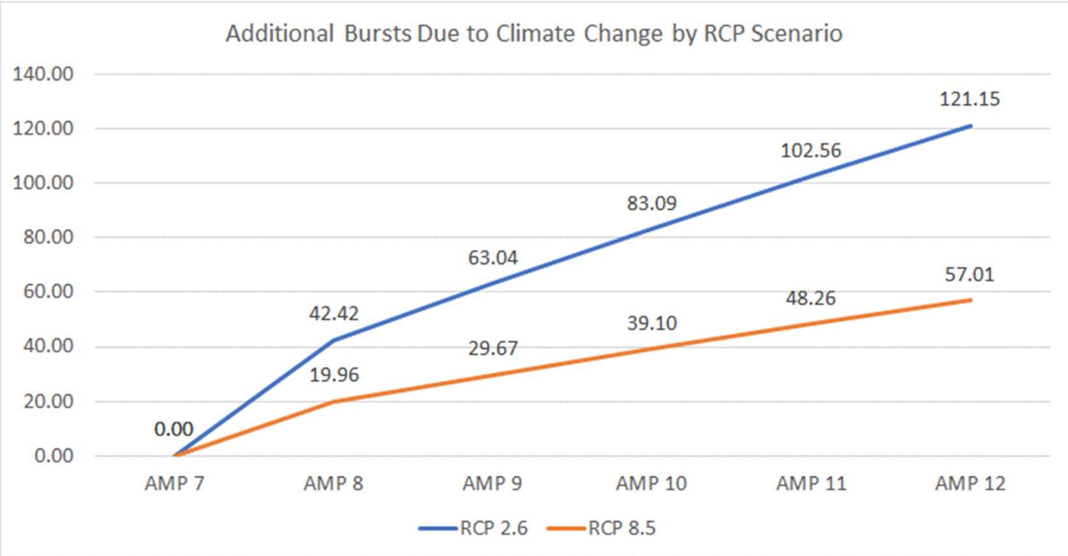

Figure 10 - Additional Bursts Due to Climate Change by RCP Scenario

Following this, the baseline PIONEER deterioration curve was reassessed to obtain a £300m additional mains replacement adjustment required to maintain stable serviceability (assuming a figure of approximately £220 per m) to mitigate against climate change in RCP 8.5 scenario.

[10] Atkins Ltd, 2021. *WRSE Climate Data Tools Scaling Report v0.4*

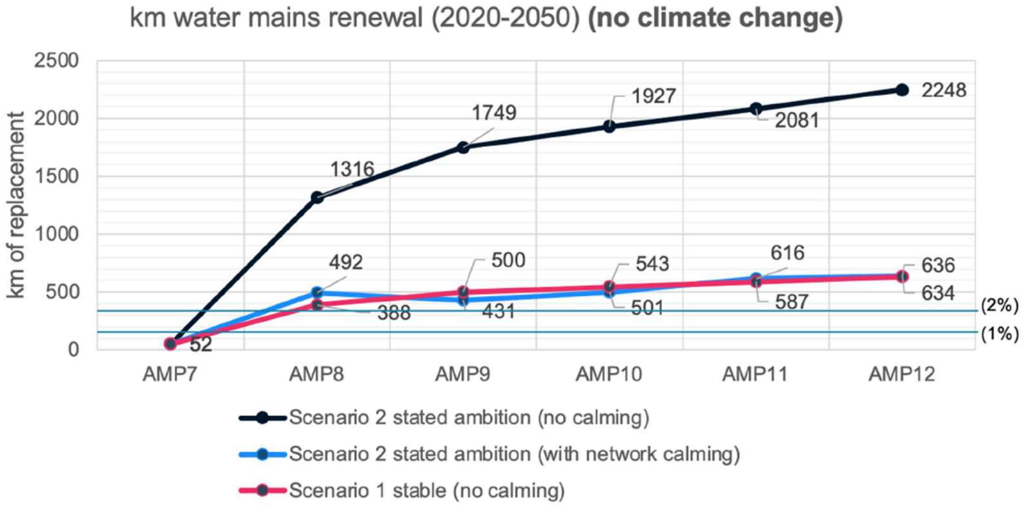

Figure 11 - Main Renewals excluding Climate Change Impact

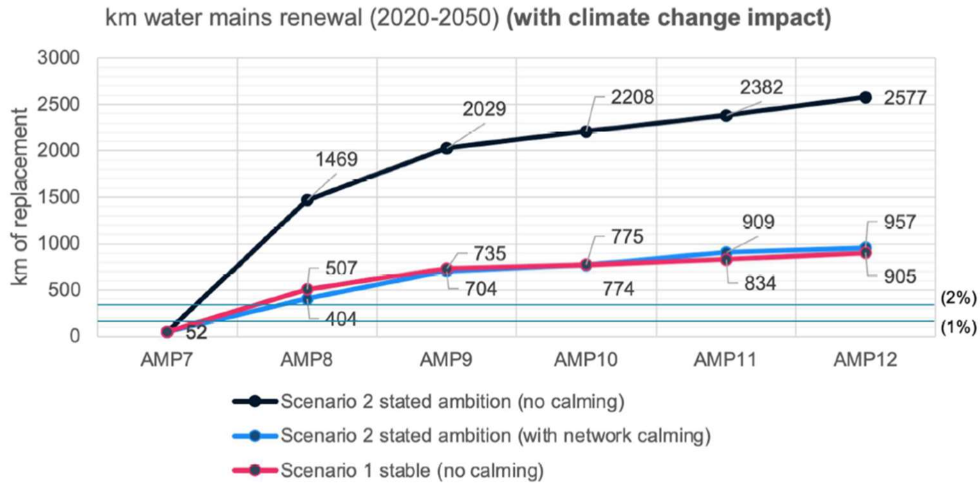

Figure 12 - Main Renewals including Climate Change Impact

Given the substantial investment required for traditional mitigation methods such as main renewals when including climate change impact as seen in the graphs above, a combination of network calming and use of innovative technologies became essential to mitigate against climate change effects in both the RCP 2.6 and RCP 8.5 scenarios. Network calming was observed to be a significant mitigation against these impacts and its adjustment is discussed further below.

Refinement of the Network Calming Approach

After phase 2.2 refinement, there was still confidence that the network calming approach can deliver the long-term Network Strategy ambitions and could be achieved for far less than traditional approaches (mains replacement) over the 25-year period. The preferred Network Strategy option (as agreed by the NSSG) is Option 19, with a 25-year Totex of £638.2m. Option 19 will achieve our agreed ambitions (Scenario 2 – Stated Ambitions).

The network calming business case approach was developed based on emerging insights captured from across the industries previous approaches to network calming and their results. This process was validated by external consultants, PA Consulting. Following this validation, we conducted an internal review and fine-tuning of program benefits to align with Affinity Water's specific network characteristics and incorporate valuable lessons learned from past experiences. As a result of these adjustments, it was projected that in AMP8, the full implementation of the network calming programme will deliver 87-burst benefits, 6.63% interruption to supply reduction, 8.6 Ml/d leakage reduction and a 0.52% CRI reduction. Stakeholders were actively engaged in this process to confirm and challenge the above outcomes derived from the refined network calming approach.

After internal discussions with stakeholders, we established the criteria for determining which components of the Network Calming program would be funded through base and enhancement funding.

Network Calming Enhancement activity:

- These activities aim to enhance the resilience of our asset systems, particularly in the face of high-impact, low-probability events.
- Investments under this category focus on laying the foundation for countering the effects of climate change and exploring innovative technologies beyond conventional approaches.

Network Calming Base programme activity:

- The base program activities primarily rely on conventional technologies. Its key objective is to maximise the utilisation of conventional technologies, ensuring sustainable asset health.
- This base program needs to operate in conjunction with our main renewals base program and is an integral part of our comprehensive 25-year asset strategy. Investments in the base program are not directed towards mitigating the impacts of climate change.

With the above changes, the enhancement network calming business case components were finalised, and it focus on the three innovative technologies that has not been previously implemented in Affinity Water. These innovative technologies will help us to build confidence to an uncertain climate change impact and set the groundwork to mitigate against it, marking the initial step change towards transforming our network into one that is optimised and resilient in the face of current climate change scenarios.

The enhancement final costs for AMP8 equate to £8.78m and the expected benefits by the end of AMP8 is a reduction in bursts of 10.03, a reduction in leakage of 3.37 Ml/d and a reduction in interruptions to supply of 6.09%.

These finalised costs and benefits have been used for the economic assessment and the mains renewals business cases. The costs and benefits for each part is shown below in Table 10:

Programme	Base/ Enhancement	Component	Capex (£m)	Ongoing Opex Annual (£m)	AMP8 Burst Benefit	AMP8 ITS Benefit	AMP8 Leakage Benefit	AMP8 CRI Benefit
Critical Valve & Smart Valve Ops Programme	Enhancement	Smart Valves for all DMA boundary Valves	£2.25	£ -	0	5.5%	0.0	0.0%
Watchkeeper Programme	Enhancement	Permanent Trunk Main Transient Monitoring	£2.18	£ -	2.77	0.5%	0.0	0.0%
Enhanced Pressure Management	Enhancement	Pressure Management Optimisation	£4.36	£ -	7.26	0.1%	3.37	0.1%
Enhanced Pressure Management	Base	New PRVs and Controllers	£14.58	£0.29	73.43	0.5%	5.23	0.4%
Digital Integration	Base	OT/IT integration	£3.01	£0.06	0	0.0%	0.0	0.0%
		Enhancement Total	£8.78	£ -	10.03	6.09%	3.37	0.12%
		Base Total	£14.58	£0.35	73.43	0.45%	5.23	0.4%

Table 8 - Breakdown of Benefits and Costs for the Base and Enhancement Programmes

Economic Assessment

We have used our PIONEER models to economically analyse many different scenarios and to determine the costs and benefits for the different options. A number of these options were selected for additional economic assessment to verify the cost benefits, the choice of the final preferred option, and to enable a standardised approach for the analysis of our long-term delivery strategies.

Economic Assessment Approach

We have rigorously followed a robust methodology for the economic analysis using the UK HM Treasury Green Book (2020) approach as the basis for the calculations. We have developed a spreadsheet to undertake the analysis for the different options and to calculate the NPV's and benefit / cost ratios (see Appendix 5). The use of the spreadsheet enables a very flexible approach to be taken for the analysis, as we can develop several options for analysis, undertake sensitivity studies, and combine projects for analysis, as necessary.

We also use our Copperleaf system to replicate and consolidate different projects and programmes of work across the whole asset base for our PR24 submission. Copperleaf acts as the master for all our investments and looks at the environmental and community and performance metrics across the whole investment portfolio. Copperleaf also acts as a check of some of the economic calculations.

The key features of our economic analysis approach include:

- Whole life costs, benefit, and dis-benefit calculations
- Net present values calculated over a 30-year period
- Options presented in 2022/23 cost base
- Benefit valuations and metrics have followed Ofwat's methodology for performance commitments, WINEP (Water Industry National Environment Programme) methodology for environmental and community benefits, and supported by industry standard sources for other areas
- In a few areas we have used our own willingness to pay valuations based upon our own research and other published research. This is either where there is no other information, e.g., low pressure, or to support sensitivity studies
- All benefit metrics and valuations are held in our Service Measure Framework
- Use of the Consumer Price Index with Housing Costs for indexation for costs and benefits
- Use of the RCV and the Spackman approach for capitalisation
- We have depreciated the financial costs using a Weighted Average Cost of Capital (WACC) of 2.92%, which is consistent with the value used for the development of our Long-Term Delivery Strategy

Cost Estimation

In summer 2022 Mott MacDonald completed work for Affinity Water to derive the unit costs for all asset classes for the infrastructure and non-infrastructure network.

These unit costs represent the current industry costs. The updated costs have been uploaded and are used within our asset management system, PIONEER. PIONEER has been used to optimise our network calming investments for AMP8.

The individual components that make up the network calming business case has been verified against the rates presented by Mott MacDonald, and the rates being used within PIONEER. We therefore have high confidence in the proposed costs associated with this business case.

One limitation of the cost estimation is that the unit costs are correct to summer 2022, however prices could increase or decrease prior to the start of, and throughout, AMP8. The PIONEER model includes the expected inflationary uplifts, and the mains renewals business case is costed accordingly, but this is not reflected in the unit costs for the components of this business case.

Benefit Estimation

We have focused our benefit quantification on the use of our Service Measure Framework benefit metrics and have used the associated benefit valuations published in the Ofwat and WINEP methodologies and other sources.

We have also considered other benefits such as cost savings, additional revenue, and other performance metrics where they are applicable. We have focused on identifying and estimating the most material benefits and used these to determine the financial valuations. In general, the fewer material benefits are quantified or discussed. Therefore, our economic justification is intrinsically conservative by nature and simplistic and transparent in approach.

In some areas, we have had to estimate the major metrics. If these have a material impact on the analysis, then we have undertaken sensitivity studies. Where the benefits are less material, we have, where possible, qualitatively assessed the benefits rather than include them in the economic analysis.

For each benefit, we have considered the timing of the benefit realisation and duration of the benefits over time. For example, is there is any lag before the benefit will start to materialise? Is there is a phased benefit realisation? And will the benefits diminish over time? As such, we have developed a profile for each benefit over time.

Assumptions Made

We have made several assumptions in our economic analysis. These are designed to be conservative by nature to account for the significant uncertainties that are inherent in the benefit monetisation.

By making conservative assumptions and undertaking sensitivity analysis, we can be confident that the overall analysis is sufficiently robust to support the investment decisions. Our assumptions are detailed below. Where “Company A” is mentioned, these are insights from PA Consulting, where for privacy reasons, the name of the company had to be emitted prior to sharing the results with Affinity Water.

- **Reduction in Bursts:**

Programme	Base/ Enhancement	Part	AMP8 Burst Benefit	AMP8 Burst Benefit	Burst Benefit Assumptions
Watchkeeper Programme	Enhancement	Permanent Trunk Main Transient Monitoring	2.77	0.11%	Remaining 4% of max 40% assumed trunk main calming achieved through permanent monitoring
Enhanced Pressure Management	Enhancement	Pressure Management Optimisation	7.26	0.29%	Burst benefit is calculated by reviewing the potential for optimisation within the infrastructure network. The burst benefit is then calculated by the Capex cost / £600,000 (conservative value based on the cost of reducing the number of bursts by mains renewals).
		Total	10.03	0.40%	

Table 9 - Reduction in Bursts Assumptions

- **Reduction in Interruptions to Supply:**

Programme	Base/ Enhancement	Part	AMP8 ITS Benefit	ITS Benefit Assumptions
Critical Valve & Smart Valve Ops Programme	Enhancement	Smart Valves for all DMA boundary Valves	5.50%	Assumes a 10% improvement in Distribution ITS performance (based on Smart Valve programme instituted in Company A) Calc = 55% ITS minutes are distribution mains x 10%
Watchkeeper Programme	Enhancement	Permanent Trunk Main Transient Monitoring	0.45%	Based on historical data (2010-2020) trunk main failures account for 11% of all mains failures and 45% of all ITS minutes. Therefore, Trunk mains bursts have a factor or 4.09 more ITS minutes than distribution main bursts
Enhanced Pressure Management	Enhancement	Pressure Management Optimisation	0.13%	Based on historical data (2010-2020) dist. main failures account for 89% of all mains failures and 55% of all ITS minutes. Therefore, Trunk mains

				bursts have a factor or 6.17 more ITS minutes than distribution main bursts
		Total	6.09%	

Table 10 - Reduction in Interruptions to Supply Assumptions

- **Reduction in Leakage:**

Programme	Base/ Enhancement	Part	AMP8 Leakage Benefit (Mld)	Leakage Benefits Assumptions
Enhanced Pressure Management	Enhancement	Pressure Management Optimisation	3.37	The benefits have been calculated based on current leakage statistics in areas where optimisation to the network can be applied.
		Total	3.37	

Table 11 - Reduction in Leakage Assumptions

- **Reduction in CRI**

Programme	Base/ Enhancement	Part	AMP8 CRI Benefit	CRI Benefit Assumptions
Enhanced Pressure Management	Enhancement	Pressure Management Optimisation	0.09%	Scaled from ITS benefit and reduced to 1/3 (only impact distribution part of CRI
		Total	0.09%	

Table 12 - Reduction in CRI Assumptions

- **Reduction in Costs:** It has been assumed that the reduction in leakage will prevent the requirement of approximately £2.6m OPEX across each AMP due to a reduction of requirement for manual searches for leaks.
- **Residual Benefits:** It has been assumed that there will be an additional 1% of the existing benefit to the burst reduction per AMP, following the inclusion of all components of the network calming business case. It has then further been assumed that this 1% additional burst benefit will also translate to an additional 1% reduction in interruptions to supply, leakage, and CRI.

We assumed that all these benefits will be delivered with a flat profile investment during the 5-year cycle. But our intention is to accelerate the investments in the first 2 years to ensure that we achieve our leakage targets.

Uncertainties and Sensitivity Analysis

The most significant uncertainties are with the benefit metrics, valuations and the timing and duration of the benefits. We have used the Ofwat and WINEP valuations wherever possible and have focused our attention on the metrics and the benefit profiles.

We have made conservative estimates for when benefits will start and finish, and how they increase and decrease over time. As such, our economic analysis is inherently conservative by nature. We then consider the benefit metric for sensitivity studies as this becomes the most material uncertainty in the analysis.

Within our spreadsheet we use the goal seek function to determine the value of a metric of concern that would be required to make the scheme cost beneficial. This provides a sensitivity check on the metric and enables commentary on the reasonableness of the economic analysis. We have run sensitivity checks on all significant benefit metrics.

Our overall option development as identified the following areas of uncertainty:

- Climate change – difference between low emission (RCP 2.6) and high emission (RCP 8.5) climate change scenarios in WRMP
- Benefits range for calm networks – is worst case as articulated in Network Strategy phase 2.1
- Growth – linked to WRMP and ONS ranges
- Demand management – assumptions of success in reducing PCC without economic measures (e.g., tariffs) – this may require an increase in leakage reduction and so mains replacement
- Approach less sensitive to technology – current calming assumptions are based on established technologies and maybe able to move faster (higher calming scenario) and require less mains replacement

Third Party Assurance and Audit Trail

The network calming programme has been originally developed during the optioneering process for the Network Strategy undertaken by PA consulting. The development of the strategy was carried out through two phases, during each phase, every output has been reviewed and scrutinised by Affinity internal experts, and then feedback iterated into the next element of work until its completion. Additionally, initial peer review process was applied following the completion of the business case.

The business case has been reviewed externally by QASR and Baringa. Feedback from these reviews have been addressed (Figure 13 shows some of this review), and then reassured and validated internally by in-house experts through peer review. There will be a final and independent third-party assurance audit undertaken by Atkins.

Network Calming

Best option for customers

Ofwat's assessment criteria	RAG assessment of EC against criteria	Baringa commentary on RAG assigned and areas for further development
a) Has the company considered an appropriate number of options over a range of intervention types (both traditional and non-traditional) to meet the identified need?		Some good evidence of different options being considered, but the optioneering section is hard to follow and needs a clear narrative and structure.
b) Has a robust cost–benefit appraisal been undertaken to select the proposed option? Is there evidence that the proposed solution represents best value for customers, communities and the environment over the long term? Is third-party technical assurance of the analysis provided?		Some good evidence of cost assessment of a range of options but needs to be presented in a clearer narrative.
c) In the best value analysis, has the company fully considered the carbon impact (operational and embedded), natural capital and other benefits that the options can deliver? Has it relied on robustly calculated and trackable benefits when proposing a best value option over a least cost one?		Selection of the preferred option over the least cost option needs to be more clearly explained.

Figure 13 - External Review Extract from Baringa

Option Assessment

Commentary on the Economic Assessment

The network calming programme includes several different activities to calm and optimised our network. Each measure provides slightly different benefits, and some are more cost effective than others. The analysis has looked at several options to investigate the relative benefits resulting from the different measures.

We understand that our network calming activities will contribute to reducing the number of mains repairs; addressing leakage; and reducing the number of interruptions to supply. Our economic assessment focuses on these benefits.

We have also identified several other benefits, such as: reducing the costs to repair bursts; cost savings from less searches for leaks; and longer asset lives. These have not been quantified or included in the economic analysis as they are difficult to estimate and not as material as the main benefits. We have also identified a small CRI benefit.

Preferred, Best Value, Option

Our economic analysis has confirmed that the preferred option is strongly cost beneficial with a total benefit NPV of £20m and a benefit cost ratio of 2.8. Most of the benefits result from reduced interruptions to supply and leakage. The benefit associated with mains repairs is of minor importance (0.4%).

Least Cost Option

The least cost option is the same as the preferred option, which has been optimised by PIONEER whilst investigating a wide range of options.

Efficiency

By making enhancements to calm our network and mitigate against climate change, we are extending the life of our infrastructure assets. Pressure optimisation and transients monitoring activities will reduce stress in the network leading to a calmer network. While these enhancements may not directly address the underlying deterioration of the network, it will improve its efficiency by improving the whole life costs of the assets and delaying the requirements for mains renewals.

Network calming initiatives demonstrate their environmental benefits by reducing carbon emissions. Compared to the carbon intensive process of mains renewals, these measures prove to be more sustainable and eco-friendly approach.

In terms of operational advantages, network calming leads to a reduction in supply interruptions, leakage, and bursts. These improvements translate to reduced operational costs and enhanced customer satisfaction.

Justification of the Preferred Option

The network calming programme is part of a much wider strategy that forms part of our WRMP and our network resilience strategies. This is a holistic strategy and approach, and this business case cannot be considered in isolation.

Customers have indicated support for investing in resilience particularly in reducing bursts and leakage. However, our programme must be appropriate, affordable, and deliverable and we, therefore, need to focus on the areas that provide the highest benefits to customers first. We need to be confident that our investments are no regrets and that we only invest at a rate that matches the increasing risk. To achieve this objective and our long-term targets for leakage and interruptions to supply, we must utilise network calming techniques within our wider strategy.

Our enhanced preferred option for network calming has been selected above the others because it maximises the reductions in leakage and interruptions to supply focus on innovative approach. It includes a range of network calming measures and maximises these over the AMP to gain the most overall benefit in the most cost-effective way. The burst reduction from the enhancement business will lay the foundation for addressing the effect of climate change and start building confidence and gain valuable experience in tackling this emergent risk, which meets the requirements of this business case as per the long-term delivery strategy. The combination of the enhancement and base network calming business cases collectively offers the most cost-effective method of reducing the number of bursts within our network. Our PIONEER modelling shows that our network calming enhancement activities only cost £0.65m/burst compared to mains repairs targeting climate vulnerable mains cost £0.9m/burst.

Our economic analysis shows a strong benefit cost ratio of 2.8 for our preferred option, demonstrating that network calming is a very cost-effective approach to reducing interruptions, bursts, and leakage. There are other benefits too such as CRI with minor benefits. Reducing and optimised the pressure in the network is also expected to extend the life of the network and hence reduce costs to customers over the longer-term. The benefits from leakage lower the requirement for manual searches for leaks through active leakage control, and the lowered interruptions to supply benefits our customers' satisfaction.

Our extensive optioneering and PIONEER modelling, undertaken as part of the wider Network Strategy development, has optimised our base and enhancement network calming activities to achieve our Performance Commitment targets and deliver our WRMP. This has selected the preferred option, which is also the least cost option and offers overall best value to customers. As part of this process, we have considered and discounted doing less or more within the AMP and optimised the use of the available network calming activities.

Doing more was discounted on the basis of the overall affordability of the AMP8 Programme, deliverability concerns and our confidence in delivering the benefits from some of the more novel techniques. We are planning to undertake innovative trials, through the OFWAT innovation fund, to investigate the cost and benefits of the newer methods. We then intend to deploy the successful trials in future AMPs, as a part of the long-term delivery strategy should they prove to be cost beneficial.

Delivery Considerations

Related Projects

This enhancement network calming business case is an integral part of our Network Strategy and supports the delivery of key Performance Commitments and our WRMP objectives.

Mains Renewals Business Case – The primary focus of the network calming enhancement business case is to mitigate the effect of climate change on the frequency of bursts within the network, whilst reducing the requirement for mains renewals in AMP8 to meet the companies stated ambition for burst levels, between base and enhancement business cases. It has been shown through PIONEER modelling that without network calming, there is a significantly higher investment requirement for mains renewals, over AMP8 and the longer-term.

Leakage - The other primary focus of the network calming, between the base and enhancement business cases, is to reduce the leakage rate by 8.8 Mld. This is linked with the leakage business case, where it has been approximated that it will require an additional £2 million to reduce leakage by 8.8 Mld through active leakage control.

Delivery Risk Management

There is a requirement to review the supply chain capacity and configuration due the projected increase in mains replacement. This is a common challenge across the sector. This could lead to potential exhaustion of the skill base and requires a potentially more radical approach (e.g., a regional framework to share supply chain resources for mains laying/pipeline design). This is also likely to drive an initial increase in unit and material costs due demand outstripping supply (e.g., for HDPE and Ductile Iron).

In addition to the raw material challenges, there is also a component supply chain risk (current shortages may continue for semiconductors for loggers, monitors etc). which are critical to the success of this programme.

These issues are already being considered by our Procurement Department to mitigate the potential risks.

Further detail regarding how we have ensured the deliverability of our full investment portfolio is provided within AFW 32 Deliverability of our Plans.

Monitoring and Reporting of Benefits

The level and type of monitoring and reporting is dependent on chosen delivery/procurement route. The monitoring of the benefits of the Network calming business case will encompass evaluating the leakage reduction, reviewing the burst performance in optimised pressure areas in a monthly basis, and focusing on Climate change monitoring to adjust our projected climate model.

Supporting Information

Appendices

All appendices can be made available upon request.

Appendix 1 – What our Customers and Stakeholders Want

Appendix 2 - Strategic Direction Statement

Appendix 3 – Affinity Water Network Strategy

Appendix 4 - Members of the Network Steering Group

- Director of Asset Strategy & Capital Delivery
- Director of Customer Delivery
- Head of Strategic Asset Management
- Head of Leakage Operations
- Head of Investment Programme Management
- Head of Water Quality Services
- Head of Asset Planning
- Head of Programme Governance
- Head of Regulation and Strategy
- Temporary Head of Regulation and Strategy
- IT Support
- Emergency Planning, Alternative Water and Performance Lead
- Senior Asset Planning Manager
- Investment Optimisation & Costs Manager
- Programme Manager
- Non-Infra Strategy Manager
- PA Consulting
- QASR

Appendix 5 – Economical assessment Cost And benefit Analysis

Appendix 6: AFW08 – Costing and Investment Portfolio Optimisation

Appendix 7: AFW19 – Price Control Deliverables

Affinity Water

Flood Resilience

August 2023

Contents

Summary

Our long-term strategy is to ensure that our network and treatment facilities are resilient to a range of external risks including the impacts of climate change. A first step in this process is to ensure that our asset health is sufficient to continue to operate and deliver service to customers. As such, we have developed a base investment programme to continue to maintain and improve the health of our existing assets. As part of this we have started to fully adopt Ofwat's Operational Resilience Framework and incorporate the principles and methods into our asset and corporate planning processes. We have already improved our asset health reporting, data capture and analysis, and we intend to make further significant improvements in this area in the future to improve how we identify and prioritise our future investments for resilience.

Our enhancement investments for resilience will go further and focus on protecting against increasing climate change impacts on our ability to supply water. Protecting our key treatment works from flooding events supports our long-term resilience delivery strategy and, in particular, our climate change pathway. The investments also align and integrate with our WRMP and WINEP strategies.

Climate change is predicted to increase the risk of flooding by up to 20%. This means that severe weather events will become more common, and rainfall will become more intense. This will lead to increased river flows, a rise in ground water levels, and more surface water runoff. As a result, the likelihood of our flood prone production sites being affected is higher, and could impact on our ability to produce and deliver water to customers.

We have carried out flood resilience works to protect our sites from fluvial and groundwater flooding risks since AMP5. However, pluvial flooding was not assessed previously as there was no information available on pluvial flood risks. This business case builds on our previous work and proposes that a £2m enhancement investment is made in AMP8 to provide resilience against the impacts of extreme flooding events at our highest risk production sites to safeguard customer water supplies.

Customers have indicated support for investing in resilience particularly in reducing bursts and leakage. However, our programme has to be affordable and deliverable and we, therefore, need to focus on the areas that provide the highest benefits to customers first. We need to be confident that our investments are no regrets and that we only invest at a rate that matches the increasing risk.

Estimating the risks and how best to mitigate these is complex. We have, therefore, undertaken economic assessments in each area to select the best value solutions and optimise the level of investment in AMP8. Our economic analysis builds upon our Risk and Value workshops that undertake in-depth assessments to better understand the resilience risks and how best, and when, to mitigate these. This has shown that it is better to invest less and focus on the highest risk and most cost beneficial areas first, and then invest more in later AMPs if and when our understanding has improved. We have considered options to increase the investment levels, but, although these are also cost beneficial, the uncertainties and level of benefits are not shown to be as attractive for customers.

Project Details

AMP8 Spend	2025-26	2026-27	2027-28	2028-29	2029-30	Total
Capex (£m)	0.04	0.11	0.44	0.32	0.10	**1.01**
Opex (£m)	0.00	0.00	0.01	0.02	0.02	**0.05**
Totex (£m)	0.36	0.11	0.45	0.35	0.99	**1.06**
Drivers						
100%	Resilience					
Benefits						
Loss of Production Capacity (Ml/d)						
Economic Analysis						
NPV Costs (£m) (2025-55)		**1.2**	NPV Benefits (£m) (2025-55)			**1.4**
NPV (£m) (2025-55)		**0.3**	Benefit / Cost Ratio			**1.2**

Six Capitals					
Natural	**Social**	**Financial**	**Manufact.**	**Human**	**Intellectual**
	★ ★ ★	★	★ ★		★

Project Description

This business case sets out the investment needed to provide resilience against the short, medium, and long-term impacts of flooding. We plan to target investment to increase the flood protection at our physical above ground assets and embed procedural changes to enable better management of flood events with the aim of safeguarding water supplies to our customers.

The flooding business case is made up of a range of well researched and costed solutions and it aims to provide the best value for money, ensure compliance, and provide resilience to our operations and our customers. We have improved our understanding of our flood risks and the associated impacts. We have reviewed our existing flood contingency procedures and have collaborated with local flood authorities to develop community flood management strategies. We have found that the consequences resulting from climate change flooding on our productions sites are significant and need addressing.

Our proposed investment reflects the effort and activities to manage all type of flood risks across the company. Through this project we aim to build upon our many years of flood management experience, to protect all our flood prone sites using a wide-range of flood protection approaches. In AMP8, we aim to continue to meet our long-term ambition by:

- Reviewing and evaluating our flooding risks and our existing flood protection
- Continuing our long-term programme of physical protection works on our above ground assets that are prone to flooding with measures such as:
    - Repositioning of our electrical distribution cabinets above the flood level
    - Raising the headworks of boreholes
    - Sealing of ducts into buildings and chambers
    - Installation of flood covers over ventilation louvres
    - Drainage improvement works
    - Installation of flood protection doors
- Provision of flood vehicles and training of use

Project Development

Baseline Assessment

Within the past 25 years, Affinity Water has experienced three prominent flooding events (2001, 2007 and 2014). On each occasion, the events caused severe distribution; damaged our above ground infrastructure; and led to a temporary loss of strategic water supplies.

The flooding event that we experienced in 2001 was not well documented, but available records suggest that the impact was widespread. Flooding in 2007 affected many of our sites resulting in temporary loss of production at key production sites. Following the 2007 flooding event, we undertook a Flood Risk Assessment[1] for production sites within our central operating region (excluding our Brett and Dour communities). The assessment identified which of our sites are at risk of fluvial and groundwater flooding, as well as to what extent. The impact of pluvial flooding was not assessed as a part of the high-level flood risk assessment undertaken previously as there was no information available on pluvial flood risk. Pluvial flooding (Row) mapping was not released until late 2014 by the Environmental Agency.

In 2008, a Flood Resilience Feasibility Study[2] was prepared by AW using the outputs of our Flood Risk Assessment. The feasibility study proposed costed solutions to protect Affinity Water's critical assets from increasing flood risks. This formed the basis of our PR09 flood resilience business plan.

We consolidated our flooding plans in the previous AMPs and designed and delivered physical fluvial flood resilience measures to 14 of our production sites. Where appropriate, we also put in place mitigation measures against groundwater flood risk at the affected sites. The works carried out were aimed at protecting individual assets rather than entire sites to avoid increasing the flood level elsewhere. These works included installation of flood doors, duct sealing, drainage alterations, raising of electrical equipment, raising of borehole headworks, waterproof tanking, and minor civil works.

A contingency plan[3] was also prepared in for our surface sites at Chertsey, Egham, and Walton. This contingency plan provides guidance to support the management of different flood event scenarios should we experience a flood warning at these sites.

Again, in 2014, Affinity Water production sites were adversely impacted by flooding. We had to shut down our production sites due to critical asset damage, high bacteriological counts, and site inundation with sewerage contaminated waters. The impacted sites are summarised in the table 1 below.

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1 Flood Risk Assessment, Jacobs UK Limited, 2008 (Appendix X)
2 Flood Resilience Feasibility Study, Mace Limited, 2008 (Appendix X)
3 Assessment of Works to Mitigate Flood Risk at Surface Water Sites, 2015 (Appendix X)

Table 1: Summary of Sites impacted by the flooding in 2014[4]

River & Surface Water Flooding (Fluvial & Pluvial)	Groundwater Flooding	Access Issues Caused by Flooding Events	Water Quality Incidents Caused by Flooding Events	Lost Site Output Caused by Flooding Events
▪ Chalfont St Giles ▪ Chertsey ▪ Hughenden ▪ Springwell ▪ Denge ▪ (Observation ▪ boreholes) ▪ Essendon ▪ Hunton Bridge ▪ Sacombe ▪ Thaxted	▪ Chalfont St ▪ Giles ▪ Chertsey (4th ▪ Wellfield) ▪ Hughenden ▪ Springwell ▪ Denge (Iron) ▪ Amersham ▪ Bow Bridge ▪ Friars Wash ▪ Fulling Mill ▪ Holywell ▪ Kensworth ▪ Lynch ▪ Ottinge ▪ Well Head ▪ Worlds Wonder	▪ Chalfont St ▪ Giles ▪ Chertsey ▪ Codicote ▪ Drellingore ▪ Eastbury (Well 3) ▪ North Mymms	▪ Chalfont St Giles (raised bacteriological counts, contamination flowing through site in ▪ Misbourne) ▪ Denge (Iron) ▪ Broome (Nitrates) ▪ Chartridge (Nitrates) ▪ Kings Walden (Nitrates) ▪ Lighthouse (Turbidity) ▪ Lye Oak (Turbidity) ▪ Queens (Nitrates) ▪ Rakeshole North(Turbidity)	▪ Chalfont St ▪ Giles ▪ Chertsey (4th ▪ Wellfield) ▪ Hughenden ▪ Springwell ▪ Chartridge ▪ Codicote ▪ Essendon ▪ Sacombe ▪ Queens ▪ Worlds Wonder ▪ Broome ▪ Kingsdown

Problem Statement and Stated Need / Driver

Affinity Water provides around 900 million litres of drinking water to 3.9 million people daily across three geographical distinct regions of Southeast England. Extreme flooding events are a risk to 27% of our production sites (142 sites) as these sites either are in a river's flood plain, in an area that has a sensitive groundwater level, or where surface drainage systems are unable to deal with intense rainfall. 24 of our production sites are at risk of more than one type of flooding event, which increases the likelihood of the same site experiencing a flood that may affect water supplies. Table 2 below illustrates the number of sites and the type flooding that they are at risk of.

Table 2: Number of Site at Risk of Flood

	Groundwater[5]	Fluvial[6]	Pluvial[7]
Number Sites Prone to Flood Risks	15	33	94

4 Groundwater Flooding 2014, Affinity Water
5 Groundwater Flooding – a flood event caused by when the level of water stored underground rises due to prolonged rainfall.
6 Fluvial Flooding – a river flood event caused by water within a river overflowing its riverbanks onto surrounding land due to extreme rainfall.
7 Pluvial Flooding – a surface water flood event caused by artificial or natural drainage systems being overwhelmed due to extreme rainfall.

The 142 sites at risk of a 1 in 100-year flooding event supply over 620,000 of our customers and we estimate 5% of them could experience water supply issues related to flooding, as shown in figure 1 below. The number of people affected may be more or less than our estimation depending on the severity of the flooding event.

Figure 1: Properties with water supply risk caused by flooding

Climate Change Driver

Forecasts by the UK Met Office suggest that climate change will increase the risk of flooding by up to 20%[8]. The Technical Report for the third Climate Change Risk Assessment (CCRA3) identifies a wide range of potential costly impacts of climate change. It identifies under the 2°C by 2100 warming scenario that annual damages from flooding for non-residential properties across the UK is expected to increase by 27% by 2050 and 40% by 2080[9].

The cost of climate change to our business could be high and our customers water supplies will be affected as flooding of our production sites becomes more frequent. To meet our planned business outcomes, it is necessary that we invest in flood resilience to mitigate the risks of climate change and to safeguard our customers water supplies from the short-, medium- and long-term impacts of flooding.

Regulatory expectations and legislative requirements

This business case aligns with the expectations and requirements set out in the Water Industry Strategic Environmental Requirements (WISER), including the following statutory and non-statutory requirements:

- Report on understanding of risk from climate change and how they are being addressed through Adaptation Reporting Power reports (NS)
- Safeguard services and ensure risks are proactively identified and actions implemented using an adaptive planning approach (NS)
- Act in a manner consistent with the National Flood and Coastal Erosion Risk Management Strategy for England and have regard to Local Flood Risk Management Strategies (S)
- Co-operate with other risk management authorities and Regional Flood and Coastal Committees in improving flood resilience and exercising water company flood risk management functions (S, NS)

8 https://www.metoffice.gov.uk/weather/climate-change/climate-change-in-the-uk.
9 The Third UK Climate Change Risk Assessment Technical Report , 2021,Betts, R.A.,Haward, A.B. and Pearson, K.V.(eds.). Prepared for the Climate Change Committee, London

- Co-ordinate and share data and information with risk management authorities to deliver flood resilience, and with category 1 and 2 responders to manage incidents (S)
- Comply with statutory reservoir safety requirements (S)
- Engaging with stakeholders to understand service and system risks and implement solutions to improve flood resilience (NS)
- Contribute to reducing the number of properties at risk of all sources of flooding through co-funded or co-delivered schemes with other risk management authorities and other parties, including by using nature-based solutions (NS)
- Deliver sustainable drainage systems and nature-based solutions, for example by promoting these solutions through the business plan process (NS)

Our Catchment and Nature-based Solutions (C&NbS) schemes included under our PR24 WINEP will also support these requirements. Please refer to the relevant business cases.

The UK Government is required, under the 2008 Climate Change Act, to publish a climate change risk assessment (CCRA) every five years. The CCRA3 is a document published in 2022 that identifies the risks that climate change poses to multiple parts of our society and economy[10].

We aim to invest in AMP8 in flood resilience scheme to meet the WISER obligation as well as avoiding the 27% increase in asset damage set out in CCRA3 as a result of climate change to our business.

We also have an obligation to fulfil flood management requirements placed on us under the Flood and Water Management Act 2010 and the Water Resources Act 1991.

Enhancement and Base Investments

We carried out flood resilience works in the previous asset management periods across 14 of our flood risk sites to enhance the protection and reliability of the critical assets, and therefore reducing the likelihood of supply interruptions resulting from flood events.

We have and will continue to invest in both base and enhancement investment areas to provide flood resilience. Our base expenditure will improve the effectiveness of our existing flood resilience measures and manage emerging risks that may arise as we improve our understanding of our flood risks.

Our enhancement expenditure for AMP8 will deliver effective flood resilience works across production sites to:

- Fulfil our obligations set out in the WISER document
- Mitigate the impact of climate change

10 The Third UK Climate Change Risk Assessment Technical Report , 2021,Betts, R.A.,Haward, A.B. and Pearson, K.V.(eds.). Prepared for the Climate Change Committee, London

- Addressing the emergence of additional flood related supply risks influenced by abstraction reductions and our Water Resource Management Plan (WRMP)

Risks, Issues and Requirements

Flooding of our production sites creates the following water supply risks to over 620,000 of our customers:

- Interruption to supply
- Poor pressure
- Contamination

Other risks associated with the flooding of our production sites include regulatory non-compliance, unsolicited repair costs, risk of employee harm and impairment of our reputation.

During an extreme flood scenario that has a direct impact to our customers, we conservatively estimate that 5% of our customers that are supplied from flood prone production sites will be at risk of interruptions to supply and poor pressures for at least 36 hours. Mechanical and electrical assets without protection from flood waters may become damaged or cease to operate. Damaged or non-functional assets are likely to lead to loss of site outputs and cause an interruption to supply or poor pressures for our customers. The damage to our assets in a single extreme event is an estimate of £8.9m.

Flooding of our production assets risks the quality of water we supply to our customers. Floodwater can contain microorganisms hazardous to health or become contaminated by sewage and other pollutants. Assets that are not protected from flooding are susceptible to ingress of floodwaters as they are not designed to be submerged (do not have the right Ingress Protection (IP) rating). This could result in boil notices being issued to our customers in exceptional circumstances or unfavourable water compliance indices.

There was record deaths and injuries caused by flooding and water incidents across England in 2019-20. There were 111 deaths, 274 hospitalisation and 422 injuries, all of which were the highest on record. The record number of deaths and injuries is a stark reminder of the dangers of climate change.[11] This show that our employees are at risk of harm if our productions sites are inundated with floodwater. Access to maintain our assets will be impaired, giving rise to potential slips, trips and falls, as well as more severe consequences such as drowning or electrocution.

The absence of appropriate flood management measures and procedures could result in non-compliance with our regulatory and legal obligations set out in WISER, the Flood and Water Management Act 2010 and the Water Resources Act 1991.

11 https://www.yorkshirepost.co.uk/news/weather/record-number-of-deaths-and-injuries-from-flooding-and-water-rescues-across-yorkshire-last-year-figures-show-3122890

Current records suggest that 142 of our sites prone to flood risks do not have appropriate physical resilience measures or flood management plans in place.

Allocation of Costs

The enhancement business case aims to invest in flood resilience works across our production sites that have not been covered in our previous business plans, as well as addressing the emergence of flood related supply risks influenced by climate change and abstraction reductions. This business case proposes an investment in flood resilience works to enhance the company's overall operational resilience.

Using previous cost data, indexed to March 2023, we have sequenced our planned expenditure to prioritise critical assets with a higher impact from flooding and progressively mitigate water supply risks in accordance with threats caused by flooding. Physical resilience works will be delivered earlier in the 25-year LTDS period to prioritise the assets most at risk, before funding is spread out over AMPs 10-12 to maintain assets and mitigate emerging risks.

We have allocated flooding expenditure in to base and enhancement investment areas. Table 3 below provides an overview of cost allocation for both base and enhancement expenditures over the next 25 years.

Table 3 : Cost allocation of base and enhancement expenditure

	AMP8	AMP 9	AMP 10	AMP 11	AMP 12
Enhancement	£1.06m	£10.47m	£1.05m	£-	£-
Base	£1.04m	£1.60m	£1.95m	£2.54m	£3.04m
Total	**£2.10m**	**£12.07m**	**£3.00m**	**£2.54m**	**£3.04m**

Direct Procurement for Customers (DPC)

Direct Procurement for Customers (DPC) is a financing model designed for larger water infrastructure projects, allowing them to secure competitive financing. Water companies consider DPC for relevant projects by running a competitive tender to appoint a third party known as a competitively appointed provider (CAP) for designing, building, financing, operating, and maintaining new infrastructure. DPC fosters competition, encouraging innovation, and investment, leading to improved outcomes for customers. It promotes accountability among water companies and delivery partners to meet high standards of performance and efficiency for strategic water resource delivery. DPC is supported when it demonstrates value for customers and the environment. For PR24, Ofwat applies DPC by default to discrete projects above a £200m threshold.

We have thoroughly assessed the scheme's suitability for a Direct Procurement for Customers approach, and based on our evaluation, it does not meet the criteria due to its value falling significantly below the £200m Totex threshold, and that there are no other projects of similar nature to combine to create a larger programme.

Research, Pilots, and Technology Development

We constantly review Environment Agency flood data, climate change projections and potential modern technologies to appropriately adapt our approach to achieve flood resilience. When new information or recognised technologies become available, we shall evaluate their suitability to and integrate into our long-term delivery strategy as appropriate.

Customer Engagement

We have undertaken extensive engagement with our customers to build a detailed understanding of their priorities and reflected these in this business case. For more detail on our customer engagement see AFW04 What Customers and Stakeholders Want.

To ensure our plans and strategies align with our customers and stakeholders' desires, we have consolidated their needs and expectations in our What Our Customers and Stakeholder Want[12] (WCSW) document. This document provides a reliable and comprehensive evidence base for our decision-making processes and strategic planning.

Our approach involved gathering extensive evidence though daily customer insights analysis, conducting research and consultations, and analysing operation data. Engaging with a diverse range of customers has enabled us to explore similarities and differences, whilst considering different household and non-household perspectives. Additionally, we consulted with our stakeholders to understand their alignment or divergent views.

To enhance the robustness of our evidence we developed a well-defined approach and framework for gathering and triangulating customer data, with clear objectives for engagement. Each piece of collected data was carefully evaluated and consolidated in accordance with our triangulation.

We obtained input from our customers and stakeholders regarding our four ambition statements: the environment, our customers, community, and resilience. By integrating their views and preferences with through research and analysis, we obtained valuable insights into our customers' inferred flood resilience preferences.

From our findings, we discovered that customers primarily associate resilience with addressing leaks and bursts, without automatically linking it to a reliable water supply in broader teams. When we delved deeper into the matter, we found that there was an assumption that we already plan for most eventualities related to resilience.

Awareness of Resilience

Awareness of resilience issues in the UK presents a mixed picture, as third-party research reports varying levels of awareness. Some studies indicate a low awareness, while others highlight higher awareness. For instance, a study focusing on southeast water consumers reveals a lack of consensus on the drivers behind

12 What our customers and stakeholders want, A triangulation of Affinity customer and stakeholder views, V5.0 – May 2023

customer support for resilience planning and the relative importance of different factors[13,14].

Similarly, Among Affinity Water's customers, we observe similar disparities in awareness. The water community, comprising of individuals with a proactive interest in Affinity Water's performance, readily and spontaneously mentioned resilience issues, including environmental challenges, population change, leaks, and aging infrastructure. On the other hand, respondents in another focus group initially limited their thoughts to issues with leaks and maintenance[15,16].

Interestingly, a prevalent sentiment among most of Affinity Water's customers is the perception that the provision of water is a given, with an assumption that water supply will be, and should be, always available.

This mix of awareness levels highlights the need for comprehensive efforts to continue to educate and engage customers on the broader resilience aspects beyond immediate concerns like leaks, and emphasising the importance of proactive planning and preparedness for future challenges.

Views on Climate Change

The connection between water supply issues and climate change remains uncertain according to water consumers, whether they are Affinity Water's customers or not[17,18]. Moreover, linking the concept of water scarcity to a country renowned for its wet weather proves challenging, especially when hot weather is often embraced, and customers vividly remember recent significant floods[19].

When Affinity Water customers were asked about potential interruptions to water supplies in their homes, their initial focus leaned towards leaks, pipe bursts, and other operational threats. However, as other issues were discussed, environmental threats gained more prominence. A mood board of various resilience-related images was shown to customers after discussing resilience topics, and the most popular images including a deep red map depicting extreme temperatures during summer 2022, and an image illustrating plastic pollution in the ocean.

These insights emphasise the need for more effective and relevant communication strategies that address diverse customer concerns and incorporate flooding aspects of resilience to engage and educate customers effectively.

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13 Customer Preferences to Inform Long-term Water Resource Planning, Part A Evidence Review, Water Resources South East (WRSE), February 2021.
14 Customer Preferences to Inform Long-term Water Resource Planning, Part B Deliberative Research, Water Resources South East (WRSE), February 2021.
15 Affinity Water, Water Supply Resilience (Topic 29), Summary and Notes
16 Affinity Water PR24 Customer engagement, Technical Report, September 2022
17 WRSE Drought Club Research, Understanding Attitudes and Perceptions of Drought to Help Develop Drought Communications, June 2021
18 Demand Management Customer Feedback, Exploring customers views of AMP7 Demand Management Programme, Final Report, April 2022
19 Customer spotlight: People's views and experiences of water, Prepared for CCW and Ofwat, April 2022

Maintaining Water Supplies

Regarding maintaining water supply, Affinity Water customers want fixing leaks to be prioritised, followed by a focus on education, and then demand management[20,21]. However, there is minimal evidence of the desire for actions specifically aimed at securing water supplies.

Despite this, there seems to be little disagreement with the principle of investing to maintain a resilient water supply. In 2018, only 3% of residents in Affinity Water's area actively opposed the idea of investing to safeguard future water supply[22]. Although, our customers have not been directly asked about maintaining resilient water supply during extreme flooding events, their responses on other topics indicate a positive attitude toward investment if Affinity Water addresses leaks[23].

Customers perceive operational and asset-based threats as areas where we have more control. On the other hand, environmental and weather risks are deemed important to mitigate against, despite the lack of control.

Evidence of Customer Preferences

Based on our findings, it appears that our customers would prefer us to invest in flood resilience measures to protect against extreme weather events, even though they may have not initially linked water supply issues with the consequences of flooding or climate change. Both our household and non-household groups demonstrated a consensus in supporting investments for unexpected events and extreme weather conditions, exceeding regulatory requirements, and enhancing our level of preparedness.

In 2022, customer insights research was conducted to support Affinity Water's PR24 Business Plan and their long-term delivery strategies. The research involved survey results from 905 household customer and 300 non-household customers who were asked about their preferences for long-term plans in five areas: carbon, environment, hard water, lead, and resilience. Validity testing demonstrated that respondents found the survey credible and were able to make meaningful choices throughout the process.

The findings indicate that both household and non-household are supportive of investment plans aimed at enhancing Affinity Water's performance in these areas, even when considering the impact on bills. Households supported plans that exceed minimum actions in 72% of choices (2,899 out of 4,016 choices, while non-households showed support in 67% if choices (935 out of 1,393 choices)[24].

20 Water Community, Insights Summary, Topic 9: Net Zero Policy, December 2021
21 Water Community, Insights Summary, Topic 5: Exploration into climate change, November 2021
22 Additional Resilience Investment Research, Online Customer Survey Findings, August 2018.
23 Water Community, Insights Summary, Topic 8: Exploration into Intergenerational Fairness, December 2021
24 Affinity Water Customer Priorities for Long-Term Ambitions, To support PR24 and long-term delivery strategies, Quantitative Research Report May 2023 (page 38)

Preferred Scenario Results for Resilience

Survey respondents were asked to choose their preferred investment scenario for each investment area from options categorised as lower, intermediate, and higher investment scenarios. Table 4 below shows our household and non-household resilience preferences.

Table 4: Preferred Scenario Results[25]

Investment Area	Non-Household Preferred Investment Scenario (905 respondents)	Average Bill Impact	Non-Household Investment Preferred Scenario (300 respondents)	Average Bill Impact (% of current Bill)
Resilience	Higher Investment Scenario: Substantial additional planning and resources for unexpected events and extreme weather. Level of preparedness that exceeds all regulations for resilience	£2.25 per year	Intermediate Investment Scenario: Some additional planning and resources for unexpected events and extreme weather. Level of preparedness that exceeds some regulations for resilience.	1%

Overall Customer Priorities

Investing in and enhancing flood protection measures aligns with our customers' top priorities. Flood resilience measures not only safeguard against water supply interruptions but also protect water quality during extreme flooding events. Our customers' overall priorities include providing good quality water, ensuring affordable bills, and preventing interruptions to the water supply as shown below.

Table 5: Customer Priorities for Key Water Service Outcomes[26]

	Households (905 respondents)		Non-household (900 respondents)	
Key water service outcome	**Score**	**Rank**	**Score**	**Rank**
Provide water that looks, tastes, and smells good	1269	**1st**	303	**1st**
Ensure bills are affordable bills for all	598	**2nd**	27	5th
Prevent interruptions to water supply	385	**3rd**	92	**3rd**
Reduce the amount of water that is lost through leakage	357	4th	-58	7th
Ensure properties consistently receive good water pressure	132	5th	53	4th
Ensure there is enough water to reduce the risk of any restrictions on water use during a drought	70	6th	-40	6th
Reduce the environmental impact and improve natural habitats in the region	-285	7th	-87	8th
Maintain existing infrastructure for current and future customers	-330	8th	-115	9th
Improve customer service	-465	9th	143	**2nd**
Support customers to reduce their water use	-771	10th	-120	10th
Use customer and community engagement to improve Affinity Water's service and reduce environmental impacts	-960	11th	-204	11th

25 Affinity Water Customer Priorities for Long-Term Ambitions, To support PR24 and long-term delivery strategies, Quantitative Research Report May 2023 (page 41)
26 Affinity Water Customer Priorities for Long-Term Ambitions, To support PR24 and long-term delivery s-40trategies, Quantitative Research Report May 2023 (page 22) – Question: which three aspects of planning for water services Question: Which three aspects of planning for water services are the highest priority for you and your household? Which three aspects are the lowest priority for you and your household? Priorities were then ordered 1st to 11th for each respondent (4-8 being equal), and points were given to each: 3 for 1st, 2 for 2nd, 1 for 3rd , 1 for 9th , 2 for 10th, 3 for 11th.

By analysing household responses by demographic groups, we found that households with higher incomes preferred more action across all investment areas. In contrast, low socio-economic households showed a preference for less action, particularly in environmental and resilience aspects.

Generally, non-households showed a preference for enhanced action in all planning areas compared to household responses. Interestingly, no differences were found in the responses of companies based on their size in terms of turnover or number of employees, nor in the amount they pau in water bills.

Customer Protection

Customers are protected via the proposed Price Control Deliverable (PCD) metric which is based on the additional number of customers protected from climate change impact in poor pressure, water quality issues and interruption to supply.

The measurement of this PCD will be based on the number of sites protected from the impact of flooding arising from extreme weather events. Table 6 below illustrates when the flood prone sites shall be protected in the AMP cycle using enhancement allowances.

Table 6: Enhancement planned works spread over the AMP8 period

Site	Payment information	Year 1	Year 2	Year 3	Year 4	Year 5
Flood resilience	No of sites protected	0	2	0	3	1

Partnering

Collaboration and Partnering

Engagement with Stakeholders and Partners

In AMP8, we will continue to engage with other utilities, regional and local resilience forums, government bodies, water companies, supply chain partners and other bodies to improve our:

Understanding of flooding risks both at the local and regional level

Understanding of interdependencies with other utilities, infrastructure, and the supply chain

Understanding of potential interventions to mitigate risk including joint interventions undertaken in partnership with others to mitigate risk

This ensures that we will co-operate with other risk management authorities in exercising their flood risk management functions, data sharing, and working jointly on local strategies, plans and local flooding investigations.

Co-design and Co-delivery

Our long-term delivery strategy recognises the importance of partner organisations in managing flood risks and the need for effective collaboration. As such, we will work closely with our framework delivery partners, through **early contractor involvement,** to help develop ideas and solutions at the planning stage. We recognise that this provides all parties with a greater opportunity to deliver the right solution, having fully understood the requirements before entering contracts.

Strategy Development

All of our enhancement cases have been developed as part of our integrated investment portfolio that takes the first steps of our Long Term Delivery Strategy and achieving our ambitions as laid out in AFW03 Strategic Direction Statement.

Our Ambition for Flooding Resilience

Flooding is a growing concern for water companies in the UK, particularly with the increased frequency and intensity of extreme weather events due to climate change. As a responsible water company, we recognise the importance of building resilience against flooding to safeguard our customers and communities, and to maintain our infrastructure's reliability over the long-term.

Our ambition for the next 25 years is to become increasingly resilient against the short, medium, and long-term water supply impacts of river, surface, and groundwater flooding events. By investing in flooding resilience, we aim to reduce our customers' risk of water supply interruptions, and poor pressures, as well as continuing to safeguard their water quality during the likely impacts of extreme weather events.

Our long-term flood management strategy builds on the flood resilience works that we have carried out since AMP5. It is consistent with the government's flood resilience expectations set out in the Water Industry Strategic Environmental Requirements (WISER) technical document published in May 2022.

Our strategy's adaptive approach primarily considers the wide-ranging influence of climate change, population growth, and abstraction reduction scenarios. The strategy is designed to mitigate the impacts of the following flood events as indicated on table 7 below:

Table 7: Type and Magnitude of Flood Event our Core Pathway is Designed to Mitigate

Type of Flooding Event	Magnitude (Return Period) of Flooding Event Mitigated by Core Pathway
Fluvial	A 1 in 100-year event, + climate change allowance, + three hundred millimetres freeboard
Pluvial	A 1 in 100-year event, + climate change allowance, + three hundred millimetres freeboard (where reasonably practicable)
Groundwater	A 1 in 30-year, plus climate change allowance (where reasonably practicable)

Our flood management strategy aims to protect our production sites and ensure that the water supply remains unaffected during extreme flooding[27] events. We will achieve this by maintaining the quality of the water we supply and decreasing the carbon intensity of our protection measures, all without compromising the surrounding environment, or increasing flood levels.

27 Extreme flooding events of a frequencies greater than a 1 in 20-year return period are when an area of land where not normally covered by water becomes severely inundated by water, caused by heavy rainfall, overflowing rivers, overflowing dams, groundwater increases, or tidal increases.

This will be achieved through a comprehensive approach that includes gaining a better understanding of flood risks and impacts, enhancing resilience across our production sites, and collaborating with local authorities to develop community flood management strategies.

We will target investment in 142 flood-prone sites. We will follow a multi-step process towards developing best value solutions:

Figure 2*: Multi-step process towards developing best value solutions*

Our base expenditure will fund renewal of our existing flood resilience infrastructure at our river and groundwater production sites. We will continue to update our risk assessments with the latest Environmental Agency flood modelling data and use this information to improve the effectiveness of our existing flood management works and procedures. The risk assessments account for the long-term impacts of climate change, population growth and abstraction reductions.

Our adaptive enhancement flood plans will focus on delivering effective flood resilience works across production sites to meet the government new expectations as set out in WISER, as well as addressing the emergence of flood related supply risks influenced by abstraction reductions and our Water Resource Management Plan (WRMP). These enhancement plans shall be guided by adaptive climate change and population forecasts, in addition to a company-wide flood scenario water supply contingency plan.

The investments within AMPs 9 to 12 will mark a significant step forward in our flood resilience strategy, as we look to achieve our ambition of protecting our production sites and ensure that the supply of safe and clean water to our customers is not compromised by extreme flooding events.

Our core pathway is a 'no regrets' investment strategy which strengthens our capability to achieve flood resilience. The strategy will reduce the likelihood of customers experiencing supply interruptions and low pressure as we aim to keep our assets on flood prone sites operational during extreme weather events. We estimate that 95% of flooding related supply interruption and poor pressure risks will be alleviated through our core pathway solution. Additionally, we shall also reduce the risk of generating unfavourable Compliance Risk Indices at 142 of our production sites by mitigating flooding induced threats to water quality.

The core pathway also enables us to fulfil government expectations placed on us under WISER and the Flood Risk Regulations 2009, as well as other legislation[28].

Looking ahead, in the event of more frequent flood events, flood management legislation and regulatory expectations for flood mitigation could become more stringent beyond 2050. Water companies may be required to provide flood resilience measures for a more frequent return period and greater climate change allowance.

As highlighted in our approach to scenario testing our core pathway against the Ofwat reference scenarios it was determined that there was no material impact that would require an alternative pathway. Following this testing we are confident that our core pathway is sufficiently resilient against various futures.

Additional Benefits form Core Pathway for Future Scenarios

Our core pathway mitigates the adverse impacts of climate change, population growth and abstraction reductions. This approach not only lessens the potential for flood-related damages but also yields enduring cost savings by preserving resources, mitigating losses, and curbing recovery expenditure. Furthermore, our core pathway is designed to elevate our customers' quality of life by diminishing the adverse impacts of flooding on water supplies.

Collaborating with external stakeholders, including the Environment Agency and local councils, fosters a sense of share responsibility and improves overall regional flood management.

What it Means for Our Customers

Table 8: *Summary of the impact of the LTDS costs to our customers up to 2050*

	AMP8	AMP9	AMP10	AMP11	AMP12
Cost Profile	£1,064,031	£11,479,825	£1,246,350	£1,767,534	£2,527,594
Bill Profile	£0.03	£0.25	£0.02	£0.01	£0.03
Benefit Profile	£1,411,858	£14,014,133	£12,971,917	£12,321,914	£12,060,245

Core Pathway Activities to Safeguard Future Options

Our core pathway stands as an indispensable 'no regrets' investment strategy essential even in benign circumstances. It encompasses thorough risk evaluations and dynamic planning, safeguarding the availability of future options to counteract

28 Flood and Water Management Act 2010: Part 1, Section 11 Effect of national and local strategies: England (1) In exercising its flood and costal erosion risk management functions, an English risk management authority must – (a) act in a manner which is consistent with the national strategy and guidance, and (b) expect in the case of a water company, act in a manner which is consistent with the local strategies and guidance.
Water Resources Act 1991: various requirements under act.

the effects of both high and low impact scenarios. This ensures a comprehensive and adaptable strategy to mitigate potential impacts.

Rationale of our Flooding Resilience

Identification of Core and Alternative Pathways

We understand the importance of flood resilience management in maintaining a sustainable and secure water supply. To identify options, we conducted risk and value workshops with key stakeholders, incorporating existing flood risk and impact assessments of our sites susceptible to fluvial, pluvial, and groundwater flood events. Through further analysis of our flood risks, we were able to identify gaps, emerging risks, and opportunities in our flood resilience management capabilities.

***Table 9**: Summary of Risk & Value Optioneering Process Outputs*

Risk & Value Workshop	Options	Output[29]
Fluvial (Covering 33 no. flood risk sites)	a) Do Nothing b) Optimised Flood Risk Mitigation c) Full Flood Risk Mitigation d) Partial Flood Risk Mitigation e) Minimum Flood Risk Mitigation	a) Risk Index above 100 b) Risk Index 1.19 c) Risk Index 2.78 d) Risk Index 3.71 e) Risk Index 1.54 **Recommended Option:** **b) Optimised Flood Risk Mitigation**
Pluvial (Covering 94 no. flood risk sites)	a) Do Nothing b) Optimised Flood Risk Mitigation c) Full Flood Risk Mitigation d) Partial Flood Risk Mitigation e) Minimum Flood Risk Mitigation	a) Risk Index above 100 b) Risk Index 2.32 c) Risk Index 2.49 d) Risk Index 2.88 e) Risk Index 3.01 Recommended Option: b) Optimised Flood Risk Mitigation
Groundwater (Covering 15 no. flood risk sites)	a) Do Nothing b) Optimised Flood Risk Mitigation c) Full Flood Risk Mitigation d) Partial Flood Risk Mitigation e) Minimum Flood Risk Mitigation	a) Risk Index above 100 b) Risk Index 0.47 c) Risk Index 1.54 d) Risk Index 1.15 e) Risk Index 0.75 **Recommended Option:** **b) Optimised Flood Risk Mitigation**

To assess the impact of flooding on our customers, we used Affinity Water's asset criticality data[30] for each of our production assets. This data considers factors such as the population served by each asset, the availability of asset redundancy, and our asset response and recovery time. We also conducted criticality assessments of sites prone to flood events to determine mixed approaches and solutions to mitigate the impacts of flooding on water supply, levels of service, and water quality. After refining these assessments by cross-referencing them with the outputs of flood

29 Risk Index - lowest index offers best value in relation to performance, risk, and cost.
30 Asset criticality data – risk classification of an asset based on its potential impact on water supplies in the event of failure, contained within our Maximo asset data system

resilience works previously carried out, we identified a range of options for flood resilience management as identified below in table 10:

***Table 10**: Alternative Flood Resilience Management Options*

Option #	Category	Description	Decision	Reasons for Decision
1	Baseline	**Do nothing** Manage flood impacts using existing provisions and procedures, accepting increasing risk levels	Baseline (Do nothing) Rejected	This would not support our overall LTDS ambition and would not protect our customer's supply and environment.
2	Best Value	**Core Pathway** Appropriate physical works to mitigate water supply risks over 25 years: Enhancement: 17 fluvial, 71 pluvial & 5 GW sites. Base: 14 fluvial, 8 pluvial & 6 GW sites. Develop flood risk assessments, & Flood management contingency plans.	Preferred Option / Core Pathway - Adopted	We believe this option provides the best balance of cost of delivery, achievement of ambition and feasibility to deliver as concluded by our NPV and risk & value assessments
3	Lowest Cost	**Basic Physical Works** Basic physical works to manage water supply risks: Enhancement: 12 fluvial & 6 pluvial sites. Base: 5 fluvial, 2 pluvial & 1 GW sites. Develop flood risk assessments, & Flood management contingency plans.	Pathway to be revaluated at 5-year investment cycles	This option would not provide sufficient dependable mitigation of water supply risks.
4	Midpoint	**Blended Approach** Basic & appropriate physical works to mitigate water supply risks: Enhancement: 16 fluvial, 43 pluvial sites & 3 GW sites. Base: 13 fluvial, 8 pluvial & 3 GW sites, Update of flood risk assessments. Develop flood risk assessments, & Flood management contingency plans.	Pathway to be evaluated at 5-year investment cycles	We believe this option would not provide as much value as the core pathway to achieve our LTDS ambition of best protecting our customer's supply and limit environmental impacts.

Over the next 25 years, our core pathway will deliver necessary physical interventions to mitigate water supply risk through enhancement initiatives at 17 fluvial, 71 pluvial and 5 groundwater flood prone sites. Additionally, we plan to modernise flood risk evaluations and develop both our business and regional flood management contingency strategies. We opted for our core pathway as it was identified as best value through a net present value assessment. To ensure that our actions are resilient to extreme weather events, climate change, population growth, and the impacts of abstraction reductions, the core pathway will be steered up to 2050 by an adaptive strategy.

As seen below in table 11, we have sequenced our planned expenditure to prioritise critical assets with a higher impact from flooding and progressively mitigate water supply risks in accordance with threats caused by flooding. Physical resilience works will be delivered earlier in the 25-year LTDS period to prioritise the assets most at risk, before funding is spread out over AMPs 10-12 to maintain assets and mitigate emerging risks.

	AMP8	AMP 9	AMP 10	AMP 11	AMP 12
Enhancement	£1.06m	£11.48m	£1.25m	£1.77m	£2.53m
Base	£1.04m	£1.90m	£2.45m	£3.04m	£3.49m
Total	£2.01m	£13.38m	£3.70m	£4.81m	£6.02m

Table 11: *25-Year Flood Resilience Planned Expenditure Totex Forecast*

Scenario Testing our Core Pathway and Flooding Resilience

The outcome of the scenario testing is shown in table 12 below.

Ambition	Investment Strategy	Pathway	Climage Change	Demand	Abstraction Reduction	Technology	Catchment Care
Resilience	Resilient Assets and Services Strategy	Flooding					

Pathway impacted, insufficient materiality for alternative pathway

Pathway impacted, sufficient materiality for alternative pathway

Pathway not impacted

Table 12: *Scenario Testing impact assessment against Ofwat's common reference scenarios & Affinity Water's bespoke wider scenarios, Catchment Care.*

Climate change RCP 8.5 and 2.6 scenarios:

Nature of impact

Climate change will increase the likelihood and severity of flood risks our sites face at plausible extremes. With more extreme weather events, peak flows of water courses and the pace of variation in groundwater are both forecast to increase. This will increase the number of at-risk sites and the degree of protection required at many of these sites. Our core pathway has been created based upon a mid-point of this climate change impact.

Method of testing

We tested our pathway using based upon Environment Agency climate change impact forecasts, which outlines plausible ranges of peak river flows, which can be equated to the flood risk we will face, and associated expenditure required.

Extent of impact

Our core pathway mitigates flood risk at a mid-point between the two plausible extremes. Under RCP8.5, we forecast an additional 12 sites at risk of flooding by 2050, with more extensive protection required across all protected sites. We estimate this additional cost to be a maximum of £2.31m above the core pathway within a single 5-year period, therefore not requiring an adaptive pathway, rather close monitoring in use of modular solutions to build protection in line with risk over the period. Under RCP2.6, we forecast that no additional sites are at risk of flooding by 2050. Our core pathway includes adequate protection at all these sites.

Justification and evidence
Analysis indicates that a 20% increase in peak river flows due to climate change would, on average, increase the level of flood protection required at flood prone sites by approximately 300 millimetres. We have used this relationship to forecast increased flood risk based upon forecast peak river flows from Environment Agency climate change forecasts.

Current climate change impact forecasts, published by the Environment Agency, provide forecast increases in peak river flows[31] at each of our catchments at 50th, 70th and 95th percentiles out to 2050 and beyond. Whilst precise correlation to RCP has not been possible, P50 can be broadly equated to marginally above an RCP2.6 scenario, with 95th percentile being marginally above RCP 8.5.

Our core pathway ensures resilience to a 70th percentile increase. Our AMP8 investment manages flood risk to below the 2050 50th percentile level with later investment increasing protections to the 70th percentile, ensuring AMP8 investment remains resilient even in an RCP2.6 scenario.

Published peak river flow climate change allowances show the anticipated increases in peak river flows through our key catchments are shown in tables 13-15 below.

Table 13: *70th Percentile Peak River Flow Climate Change Allowances*

Management Catchment Name	River Basin District	2020s Higher Central	2050s Higher Central	2080s Higher Central
Cam & Ely Ouse	Anglian	7%	5%	19%
Colne	Thames	16%	16%	35%
Combined Essex	Anglian	13%	16%	38%
London	Thames	14%	14%	27%
Rother	South East	19%	23%	38%
Upper Lee	Thames	9%	7%	22%

Table 14: *50th Percentile Peak River Flow Climate Change Allowances*

Management Catchment Name	River Basin District	2020s Central	2050s Central	2080s Central
Cam & Ely Ouse	Anglian	2%	-2%	9%
Colne	Thames	10%	8%	21%
Combined Essex	Anglian	7%	8%	25%
London	Thames	10%	7%	17%
Rother	South East	15%	16%	28%
Upper Lee	Thames	3%	-1%	10%

31 Peak river flow refers to the maximum rate at which a volume of water passes through a river during a period or event, such as a prolong period of frequency and intense rainfall.

Table 15: *95th Percentile Peak River Flow Climate Change Allowances*

Management Catchment Name	River Basin District	2020s Upper End	2050s Upper End	2080s Upper End
Cam & Ely Ouse	Anglian	21%	22%	45%
Colne	Thames	30%	38%	72%
Combined Essex	Anglian	27%	37%	72%
London	Thames	26%	30%	54%
Rother	South East	29%	38%	66%
Upper Lee	Thames	23%	27%	59%

Ongoing monitoring

We will reassess our flood risk across all sites on a 5-yearly basis, informed by the latest flood modelling and climate change forecasting.

Slower and faster technology scenarios:

Nature of impact

The faster technology scenario will likely increase awareness and understanding of forthcoming flood events through advances in modelling and more open data. This may improve the effectiveness of our flood resilience water supply contingency plans, but unlikely to have any material impact on the requirements of our flood resilience programme. In addition, climate and flood modelling advances will continually improve the accuracy of prediction in need, improving the cost-benefit of our investments as we improve our targeting.

Method of testing

With we have undertaken a horizon scan of current and emerging technologies that may change the solutions needed in managing our flood risks. The plausible extremes of the pace of their adoption were then considered in line with the common reference scenario.

Extent of impact

We do not forecast either slow or fast technology scenario to materially impact the requirements or cost of delivering the core pathway.

Justification and evidence

We have assessed recent advances in flood model capabilities, examining how they have improved the accuracy of flood impact prediction and the associated impact on our evaluation of flood risks. Previous advances have driven us to marginally increase expenditure in flood mitigation as we better understand flood risk for each site.

From here we have used expert assessment to forecast how these are likely to advance further over the next 25-years, to identify any likely material changes in investment levels.

Ongoing monitoring

We will monitor technological developments through our delivery partners and in consultation with flood authorities, using the latest modelling and best value flood mitigation approaches available to inform investments at each 5-year investment planning cycle.

High and low demand scenarios:

Nature of impact

We anticipate that the high demand scenario induced by population growth, will place a greater criticality on the assets we use to supply water to our customers, resulting in increased investment in flood resilience to protect all sites of a given criticality.

Method of testing

Assessment of likely population growth within each hydraulic demand zone, to determine changes in criticality of key sites that may increase investment requirements in flood mitigation.

Extent of impact

In a high demand scenario, our adaptive pathway would need to plan to improve flood resilience at a greater number of sites. The cost impact of a high demand scenario is expected to be £2,060k over 25-years to manage increases in flood risks of 11 additionally affected sites. Table 16 below illustrates the projected costs over a 25-year period, for both high and low demand scenarios. We anticipate a comparable increase in population for both high and low growth scenarios, indicating a commensurate upsurge in demand.

Table 16: 25-Year Cost Forecast for High and Low Demand Scenarios

Period	High Scenario Population Growth Percentage Increase	Expected Additional Sites Impacted by Flooding (High Scenario)	High Scenario Estimated Cost Impact	Low Scenario Population Growth Percentage Increase	Expected Additional Sites Impacted by Flooding (Low Scenario)	Low Scenario Estimated Cost Impact
AMP8	4.17%	3	£ 500k	4.11%	3	£ 500k
AMP9	3.24%	2	£ 390k	3.24%	2	£ 390k
AMP10	2.57%	2	£ 390k	2.61%	2	£ 390k
AMP11	3.01%	2	£ 390k	3.04%	2	£ 390k
AMP12	3.10%	2	£ 390k	3.12%	2	£ 390k
25-Year Total		11	£ 2,060k		11	£ 2,060k

Justification and evidence

As outlined by our WRMP forecasts, we anticipate a 15.10% population increase within our operational region by 2050, accounting for both high and low population growth scenarios. Notably, our data indicates a slight variation of approximately 200,000 in population across our entire company.

Table 17: 25-Year High and Low Population Growth Forecasts[32]

Period (AMP End)	High Population Forecast Scenario	Percentage Change in Population Between Periods (High)	Low Population Forecast Scenario	Percentage Change in Population Between Periods (Low)	Population Difference Between Forecast Scenarios	Percentage Difference Between Forecast Scenarios
AMP8	4,306,474	4.17%	4,125,946	4.11%	180,528	0.06%
AMP9	4,450,458	3.24%	4,263,912	3.24%	186,547	0.00%
AMP10	4,567,653	2.57%	4,377,960	2.61%	189,692	-0.04%
AMP11	4,709,373	3.01%	4,515,183	3.04%	194,190	-0.03%
AMP12	4,859,998	3.10%	4,660,519	3.12%	199,479	-0.02%

Using hydraulic analysis, we have calculated that these concurrent increases in demand will proportionally elevate the criticality of our water supply infrastructure. This effect is poised to result the need for flood resilience measures for an additional 11 sites that are at risk of flooding.

Ongoing monitoring
We will continue to monitor population growth and projected demands through our WRMP and assess their impact on our sites at 5-year investment cycle intervals. By regularly updating and rigorously evaluating risks, we will refine our adaptive strategy to stay effective and to adaptable.

High and low abstraction reduction scenarios:

Nature of impact
Abstraction from groundwater can materially reduce the flood risk in the vicinity because of reduced ground saturation. In addition, as we reduce groundwater abstraction, criticality of other sites is increases as our customers' supplies become more dependent upon these sites. This impact relates chiefly to groundwater risks, a small proportion of the overall expenditure.

Our AMP8 investments include investments only at sites which will not be closed due to abstraction reductions over the 25-year period, as our analysis indicates no significant flood risk to these sites over the 2025-30 period.

Method of testing
Site flood risk assessments overlaid with our abstraction reduction pathways, which detail changes in site criticality.

Extent of impact
Costs associated with mitigating additional flood risks are included within the schemes where we are planning for abstraction reductions, and therefore do not result in additional costs within the flood resilience pathway at either plausible extreme.

Justification and evidence
In AMP6, we ceased abstraction from our Fulling Mill source in as part of our sustainability reductions programme, in agreement with the Environment Agency.

32 Water Resource Management Plan 24 Reference

Following this, the Environment Agency (EA) identified an increased risk of flooding of the nearby properties built on the floodplain in the vicinity, as well as elevated flood risk to other downstream properties within Welwyn village. Under the request of the Environment Agency, to manage this risk we have recommissioned our site.

Since this incident we have sought to better understand the link between abstraction reductions and flood risks and include appropriate assessments and mitigations within our planning of such schemes.

Ongoing monitoring
To continually assess the impact of this scenario through the LTDS period, we will monitor sustainability reductions and water resources through our WRMP, as well as continually monitoring local borehole and river levels to assess the materiality of this scenario going forward.

Foundations of our Flooding Resilience

Assumptions

The proposed works at each site have been costed, based on historical data from Affinity Water's previous projects.

The flood protection design for each site was developed based on a 1:100-year event with an allowance for climate change and freeboard. To account for climate change, a 20% increase in flow was assumed. Current legislation and regulations require water companies to provide flood impact mitigation to an appropriate intensity and frequency.

For pluvial flooding, an analysis of flood risk was based on the Risk of Flooding from Surface Water maps created by the Environment Agency and Lead Local Flood Authorities in 2013. For fluvial flooding, the PR09 Flood Risk Assessment undertaken by Jacobs was reviewed to identify sites at risk. Finally, each site was considered to be affected independently of the others.

Performance Improvements From Base Expenditure

Flood resilience base expenditure shall improve the effectiveness of our existing flood resilience assets and procedures. Updating our flood risk assessments with current modelling data will allow us to improve our site-based flood management and water supply continuity plans. Existing flood protection measures shall be examined and adapted if necessary to manage forecast climate change, population growth, and abstraction reduction risks.

Table 18 below provides an overview of the flood resilience enhancement and base expenditure activities we have planned for AMPs 8 to 12.

Table 18: Flood Resilience LTDS Base & Enhancement Expenditure Activities

	AMP8	AMP9	AMP10	AMP11	AMP12
Enhancement Expenditure	**£1.06m** 3 fluvial sites, 2 pluvial sites, 1 GW sites.	**£11.48m** 14 fluvial site, 39 pluvial sites, 4 GW sites.	**£1.25m** 30 pluvial sites.	**£1.77m** Emerging flood related water supply risks.	**£2.53m** Emerging flood related water supply risks.
Base Expenditure	**£1.04m** 7 fluvial sites, 2 pluvial sites, 1 GW sites.	**£1.90m** 6 fluvial sites, 3 pluvial sites.	**£2.45m** 1 fluvial sites, 3 pluvial sites, 5 GW sites.	**£3.04m** ongoing maintenance of flood risk assets.	**£3.49m** ongoing maintenance of flood risk assets.

Uncertainties Associated with our Flood Resilience LTDS

Flood risk assessments inherently involve uncertainty, and our concerted efforts aim to significantly alleviate this uncertainty. Our approach involves integrating cutting-edge flood modelling data from the Environment Agency into our short-term flood resilience management plans. Better comprehension of flood risks will actively shape the extent of our short-term strategies, consequently moulding our overarching long-term delivery strategy. The best-case scenario would be that our current flood resilience measures were founded from conservative risk evaluations. Therefore, proving that our existing measures and procedures are robust, and that less investment would be needed to achieve our long-term flood resilience ambitions. Conversely a contrasting scenario would necessitate a larger investment than forecasted.

Beyond 2050, the uncertainty of climate change and population growth adds complexity to our adaptive planning efforts. To address this, we have outlined moderate, balanced, and extreme climate change, and high demand pathways to maintain to maintain focus on our long-term flood resilience ambitions. A core element of our approach involves ongoing monitoring of key metrics. As these metrics respond to changing conditions, they guide adjustments in our long-term flood resilience strategy.

Our pragmatic process emphasises our commitment to staying responsive and ensuring ability to mitigate flooding risks effectively.

Flood Resilience Uncertainties that Cannot be Meaningfully Alleviated

Legislative uncertainties pose a unique challenge to our long-term delivery strategy for flooding resilience. These uncertainties are rooted in the fluid nature of governance and policy making that regulate flood management. Unlike technical or environmental uncertainties, which can often be addressed through improved data or predictive modelling, legislative uncertainties are contingent on shifts in political priorities, societal values, and legal frameworks.

These uncertainties can manifest through changes in government administrations or shifts in public sentiment that may lead to alterations in funding priorities or the allocation of resources for flood prevention and mitigation. Additionally, modifications to zoning regulations or land use polices can impact the design and implementation of flood control infrastructure.

We have taken proactive measure to mitigate the potential repercussion of legislative uncertainty within our plans. Our core pathway maintains a high degree of flexibility and adaptability, enabling us to promptly respond to any shifts in legislation that might impact flood management obligations incumbent upon water companies.

Whilst it is not feasible to entirely eliminate the challenges posed by legislative uncertainties as appropriate parameters for scenario testing cannot be established, we have selected a core pathway that priorities adaptability. This approach ensures our overarching flood resilience objectives remain attainable, regardless of changes in legislation.

Optioneering

Further detail regarding how we have ensured the deliverability of our full investment portfolio is provided within AFW 32 Deliverability of our Plans.

The following section describes our approach and the assessment that we have carried out to forecast future investment requirements for flooding. Figure 3 below illustrates our process for forecasting the investment needs for flood resilience.

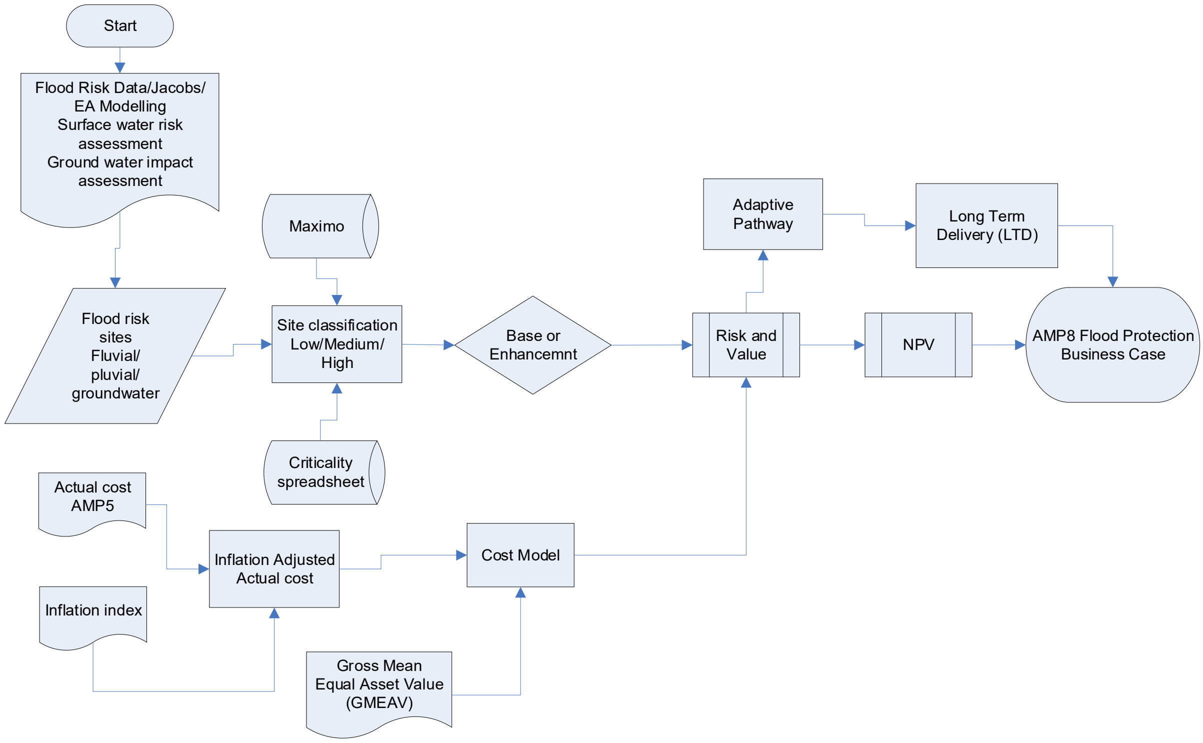


Figure 3: Optioneering Process Flow Diagram

Information from flood risk data, criticality and Maximo data systems have been used to identify sites at risk of flooding. The sites have been classified according to their criticality (low, medium, or high), and have further been classified as Base or Enhancement based on the history of flood works carried out at the site. Sites where previous flood works have been carried out are classified as "Base", and sites where we need to comply to the WISER document and mitigate against the impact of climate change are classified as "Enhancement".

This classification system provides a good foundation for the flood risk management business case. This information is used to develop an AMP8 flood risk mitigation plan that is tailored to the specific needs of the business.

Flood Risk Data

Information from the flood risk assessment by a consultant; our internal surface water risk assessment; our groundwater flooding have all been used to identify the sites at risk from all types of flooding for an average flood return period of 1 in 100 years.

The target accuracy of the flood model study is ±0.15m at each calibration point but may be greater between calibration points.

Criticality Database

Criticality is defined as a measure of the impact asset failure would have on the ability of the company to supply a sufficient volume of suitable quality water at sufficient pressure. Each asset will have a criticality indicator that will be dependent on a number of factors, or criticality categories.

The following criteria have been identified as the most suitable for assessing asset failure consequence: health and safety, environmental damage, supply performance, quality performance, asset loss, reputation loss and total cost of asset.

The assets are then categorised as high, medium, or low based on the estimation of likelihood and consequence as shown in figure 4.

Asset Criticality Matrix							Likelihood of Occurrence						
Consequence							(How often might the threat occur ?)		Event Occurs every 10 or more years	Event Occurs every 5 to 10 years	Event Occurs every 2 to 5 years	Event Occurs every 1 to 2 years	More that 1 event per year
									Not known to have happened	Known to have happened	Known to have happened in the recent history	Periodically happens	Frequently happens
(What is the business impact ?)									1	2	3	4	5
Health & Safety	**Environmental Damage**	**Supply Performance**	**Quality Performance**	**Asset Loss**	**Reputation Loss**	**Total Cost**			Rare	Unlikely	Probable	Likely	Almost Certainly
1 or more fatalities	A major release / event that would damage the environment over a long duration	> 12hr outage and is a property count event of 100s	Contamination sufficient to cause major illness and or injury	Extensive damage to multiple assets on a site (Wholesale replacement of Assets)	An event of interest to national and or international media	>£500k	**E**	Very high					
Major injury that could lead to a permanent disability, or several RIDDORs	A release / event that would damage the local environment over a short duration	> 12hr outage and is a property count event of 10s	Contamination sufficient to cause a do-not-use or boil notices to be issued	Major damage to 1 or more assets (Major refurbishment or replacement of one or more Assets)	An event of significant interest to the media	£100k to £500k	**D**	High					
Injuries that are greater than a RIDDOR event, i.e. > 3 day duration	An event with an expedience of consent limits that would lead to a prosecution	6hr to 12hr outage and is a GSS (DG) day event	The presence of PCV's and or Coliform's in the water supply and 3 day reporting or more is required	Damage to more than one asset (Repairable)	An event of interest to local topical groups	£25k to £100k	**C**	Moderate					
Minor injury but no permanent impact	An event that could jeopardise consent limits and is reportable.	3hr to 6hr outage that is a reportable event, and impacts <= 350 properties	An event that is sufficient for a regulatory notification on a drinking water quality standard, but not a breach	Damage to the asset (Repairable but parts need to be sourced)	An event of interest to local residence, and or generates a cluster report (>= 5 reports in 30mins)	£5k to £25k	**B**	Low					
An event that can be considered as equivalent to a near miss	An event that is well within consent limits and is not reportable.	< 3hr outage and is a none reportable event	An event that is well within any of the drinking water quality standards, but may breach operational thresholds	Slight damage to components of the asset (Spares readily available and repairable.)	An event with a low level of local interest	<£5k	**A**	Very Low					

Key: Red Boxes = High Criticality, Yellow Boxes = Medium Criticality, Green Boxes = Low Criticality, RIDDOR = Reporting of Injuries, Diseases & Dangerous Occurrences Regulations, GSS = Guaranteed Standards Scheme, PCV = Prescribed Concentration or Value

Figure 4: Asset criticality matrix

This list is used in the business case to identify sites that are most important to the business and that would be most at risk of damage in a flood. This data also has been used in the risk and value workshop to identify the number of people affected in an event of supply interruption and the risk that the business carries if no flood work is carried out in AMP8 .

Maximo

Maximo is an asset and works management solution which provides a single source of complete and accurate data for our above ground assets. Maximo provides asset attributes such as asset unit type, size and year of installation; maintenance information such as planned and reactive maintenance events and durations.

Maximo is used to meet statutory and regulatory requirements and to enable improved asset investment decision-making to allow us to better manage risk.

Gross Mean Equivalent Asset Value (GMEAV)

GMEAV is the cost in current terms to replace an asset of this type with is modern equivalent. It represents the equivalent replacement cost of the assets with its updated version. The GMEAV considers the development of new technologies to assess the impact of the overall replacement costs of some assets.

History of Flood Works

A review of the flood works document lists the sites and the associated flood works carried as part of the previous AMPs flood protection works. The list is used to identify the level of works carried out on a site level and whether still further work is required. This list is also used to categorise the AMP8 investment as Base or Enhancement.

Cost Model

The following steps have been followed to create the cost model to forecast the costs for the AMP8 business plan:

Gather historical data on costs: Costs from actual historical business cost gathered to use as a reference as in table 19

Analyse inflation rate over the years: inflation rate data obtained from ''Construction output price indices - Office for National Statistics'' for risk index calculation to obtain adjusting value as in table 20

Identify other factors that affect costing: Identify other factors such as labour cost and innovation

Adjust the costs using the adjusting figure: Convert the costs of the previous projects to present value using the adjusting figure obtained using the inflation rate and other factors

Identify trends: use the GMEAV of the site and the adjusted actual cost figure to identify the trends in costs

Develop a cost model: Use the identified trend to develop a mathematical formula that can be used for costing as shown in figure 5

Test cost model: Two cost models were developed and tested. The linear cost model was found to be the most appropriate to use for pricing.

Table 19: Historical cost data

Site	Total No of Assets	Total GMEAV [Column K]	Actual Cost Works 2015	Actual Cost Inflation Adjusted	Estimated Cost Logarithmic	Estimated Cost Linear
EGHAM	3882	£ 1,943,285.66	£ 984,218.24	£ 1,279,483.71	£ 835,329.33	£ 1,095,985.76
CHERTSEY	6769	£ 12,981,858.01	£ 493,069.36	£ 640,990.17	£ 802,157.93	£ 914,880.82
WALTON	3516	£ 7,922,182.13	£ 488,087.33	£ 634,513.53	£ 670,783.83	£ 472,456.95
THAXTED	373	£ 184,516.73	£ 2,143.00	£ 2,785.90	£ 450,070.24	£ 209,617.09
AMERSHAM	1818	£ 119,039.38	£ 111,875.00	£ 145,437.50	£ 389,938.67	£ 181,618.36
GERRARDS CROSS	210	£ 80,705.15	£ 110,775.00	£ 144,007.50	£ 327,089.77	£ 161,600.23
CHALFONT ST GILES	243	£ 32,125.29	£ 244,771.00	£ 318,202.30	£ 157,301.19	£ 134,204.49
FRIARS WASH	222	£ 19,370.26	£ 158,602.00	£ 206,182.60	£ 96,319.28	£ 129,571.15
BUSHEY PUMPING	108	£ 8,178.69	£ 40,132.00	£ 52,171.60	-£ 43,108.19	£ 123,726.91

Table 20: Inflation Index

Year	Inflation	Adjusting Factor
2015	1.00%	1.01
2016	2.60%	1.04
2017	2.70%	1.06
2018	2.80%	1.09
2019	1.70%	1.11
2020	1.60%	1.13
2021	5.20%	1.19
2022	9.30%	1.30

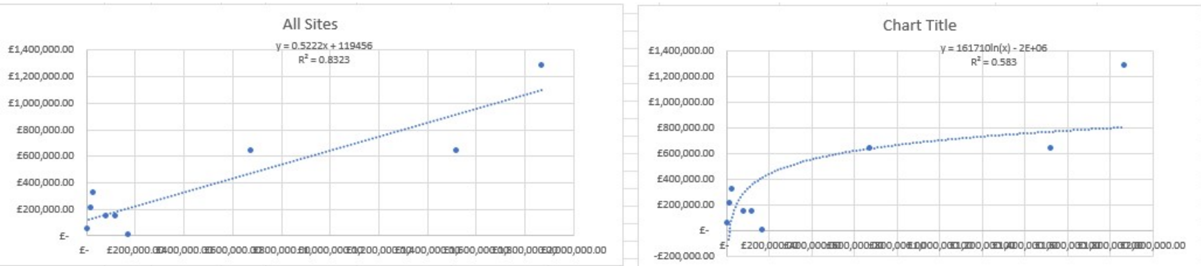


Figure 5: Estimated Linear and Logarithmic Costs

Risk and Value Process

The following section outlines the Risk and Value (R&V)[33] optioneering assessment methodology applied in this business case. We have used a comprehensive R&V optioneering assessment procedure to evaluate the value of different investment solutions identified to manage risks or opportunities associated with problems we face in delivering reliable wholesome water supplies to our customers. Value is the worth, benefit or return generated by investing in new or existing assets. It represents the economic or financial benefit that an investment contributes to our organisational objectives.

The R&V optioneering assessment procedure is an embedded process in our ongoing asset management systems and has allowed us to systematically explore

33 AMTI001, Risk and Value Manual, AW document,2022

and evaluate multiple options for achieving our long-term delivery strategies. Advantages using this process in the optioneering of this business case are shown in figure 6 below.

Building consensus through **collaborative working** – alignment

Achieving savings through **structured processes**, based on **data** to deliver best value

Clearly **integrates** with **governance processes**

Figure 6*: Advantages of using Risk and Value Assessments for Optioneering*

In essence, the R&V optioneering assessment used to inform this business case to take a holistic approach, considering the broader perspective of our customers' service risks, rather than solely focusing on the assets we manage. By adopting this approach, it safeguards against hasty solutions and prevents making poor decisions prematurely. R&V optioneering assessments do not make decisions themselves, instead they serve as valuable inputs that inform and enhance our decision-making process.

R&V optioneering assessments are a structured process that identify, analyse, and prioritise risks and opportunities to inform our option selection decisions. It offers valuable information and insights to enable best value optimisation by balancing cost, risks, opportunities, and performance benefits. The R&V process is divided into 5 unique steps, as illustrated on figure 7.

Identify the **risk / problem** → Establish the **cost of failure** → Understand the root **cause** → Creatively come up with → **Evaluate** Options

What? | How much? | Why? | What could | What's best

Figure 7: *The Stages of a Risk & Value Assessment*

Applied Level of Risk and Value Optioneering Assessment

The level of R&V optioneering assessment that is applied is determined by the combined score of the extent of understanding of the problem, the anticipated costs of the option solutions, and the complexity of the option solutions as shown in figure 8 and figure 9 below.

	Score		
Criteria	1	2	3
Understanding of Problem	High	Medium	Low
Solution Cost (Capex)	<£250k	£251k - £999k	>£1,000k
Solution Complexity	Low	Medium	High

Figure 8: *Scoring of Risk and Value Assessment Requirements*

Score	Level of R&V Required	Description of R&V Assessment Required
6 – 9	**Full**	Facilitated workshops, with subject matter expertise and wider stakeholder community, complete data validation.
4 – 6	**Medium**	Facilitated workshops, with subject matter expertise, select stakeholder community group, and with best available validated data.
3 - 4	**Desktop**	Desktop analysis , with subject matter expert input, and best available data

Figure 9*: Level of Risk and Value Optioneering Assessment*

This flood resilience scheme was assessed to have a score of 6, therefore, a medium level R&V optioneering assessment was applied. The reason for this is that we have a medium level of understanding of the problem, the probable capex solution would be above £1,000k, and the solution complexity is relatively low.

Risk and Value Optioneering Assessment Stakeholders

Desktop R&V optioneering assessments are led by an Asset Planner with relevant input from a SME. The Asset Planner follows all the R&V option assessment stages without holding workshops but may hold sperate meetings to achieve the R&V objectives.

Medium and full R&V optioneering assessments are delivered through face-to-face workshops. These workshops are held with the relevant asset management and asset user community stakeholders from different departments across our organisation including, but not limited to, Asset Management, Capital Delivery, and Customer Delivery.

Workshops are led by an independent Facilitator[34], who is supported by an Asset Planner[35] and a Subject Matter Expert (SME). Relevant stakeholders from the asset management and asset user communities provide input into R&V workshops and may also provide insights, data, and fist hand accounts of their respective experiences.

Stakeholders from the management and user community include, where appropriate, Asset Specialist(s), Asset Engineer(s), Asset Scientist(s), Programme Manager(s), Project Manager(s), Production Manager(s), Production Engineer(s), Production Lead(s), Production Technician(s), Networks Manager(s), Operations Manager(s), Customer Service Technician(s), and Water Quality Scientist(s).

The Flood Resilience Medium R&V optioneering assessment workshops was led by a Facilitator and supported by an Asset Planner and SMEs in flooding, along with a Project Manager with flood related experience, and Asset Specialists in asset protection and hydrogeology.

34 An Independent Facilitator (IF) is a professional who facilitates discussions, interactions, and decision making in an impartial and neutral manner. The IF is responsible to deliver the objectives of the R&V assessment and provides appropriate challenge to root cause analysis, optioneering and cost benefit analysis.
35 An Asset Planner is an engineering professional who is responsible for relevant data gathering, stakeholder coordination, input into the R&V optioneering assessment, and documenting the outputs.
35 Subject Matter Expert (SME) SME is an individual who possesses a deep knowledge, experience, and expertise of the subject area.

Stages of Risk and Value Optioneering Assessments

Analysing the risk and value of options is fundamental to making well-informed decisions, optimising portfolio performance, and managing potential risks in asset management. This section further explains the stages involved in the R&V assessment.

Identify the risks

The initial stage of the R&V optioneering assessment involves thoroughly identifying the risks, challenges, and opportunities associated with our customers' water supply in connection with a particular topic. The objective of this step is to ensure that all workshop attendees have a shared understanding of the current challenge.

By bringing everyone up to speed on the latest assessment of the problem or opportunity, the facilitator ensures that the discussion is productive and that all participants can contribute to the analysis of the risks, challenges, or opportunities.

We identified our flood resilience management options through risk and value workshops with key stakeholders across Affinity Water. These workshops were guided by existing flood risk and impact assessments of our sites which are prone to fluvial, pluvial and groundwater flood events. Further analysis of our flood risks made possible the identification of gaps, emerging risks, and opportunities in our flood resilience management capabilities. We have identified the following risks in these workshops for all types of flooding events:

Damage to critical infrastructure

Loss of supply to our customers

Contamination of water supplies

Inability to manage impact flood risks

Injury to personnel due to flooding event

Regulatory scrutiny and reputational damage

For groundwater flooding, water may overflow and leave our sites and flood the local environment and introduce further risks as below:

Injury to third party personnel

Damage to third party assets

Cost of failure

In this stage, we assess the cost of failure by quantifying the extent of risk and opportunities and then converting their values into monetary terms using a business service impact matrix, or Opportunity and Risk Assessment (ORA) tool. Participants of the workshop use this ORA tool to analyse the likelihood of different failure modes occurring, as well as the potential impact of those failures to calculate the financial impact of those risks. The risks identified and costed using this tool has been presented in figure 10

OPPORTUNITY and RISK ASSESSMENT: SUMMARY

Notes: Click on the ? to see the Helpsheet	Units	Fluvial	Pluvial	Groundwater
Only populate relevant green shaded cells				
Mitigated OPEX		£660,000	£1,880,000	£350,000
What is the annual value of any mitigated OPEX	£			
Water Supply Interruptions (I2S)		£90,118,374	£164,496,185	£9,979,563
How many properties are impacted by these interruptions?	No. of propertie	368545.8	672719.4	12243.65
What is the expected duration of these interruptions?	Minutes	2160	2160	7200
How many people will have their per capita consumption impacted by thi	No. of people			
For each person, how much will their daily per capita consumption be red	l/p/d			
Average Time Properties Experience Low Pressure		£28,255,176	£51,575,151	£9,386,798
What is the expected duration of these low-pressure events below 15m l	Minutes	2160	2160	7200
How many properties are impacted by these low-pressure events?	No. of propertie	245697.2	448479.6	24487.3
How many mains bursts are expected per year from this risk?	No. of bursts per year			
Event Risk Index (ERI)		£58,750,423	£58,750,423	£38,912,132
What is the ERI seriousness Score?(0-5)?	List	4HealthRiskIndicator	4HealthRiskIndicator	4HealthRiskIndicator
What is the duration of the ERI event?	Hours	36	36	72
How many people are impacted by the ERI event?	No. of people	2247357.6	2247357.6	744245.5
What is the ERI Assessment Score (1-5)?	List	4Enforcement(LegalInstrument)	4Enforcement(LegalInstrument)	4Enforcement(LegalInstrument)
Compliance Risk Index (CRI)		£40,822	£40,822	£9,025
What is the CRI Parameter Score (1-5)?	List	4HealthRiskIndicator	4HealthRiskIndicator	4HealthRiskIndicator
What is the CRI Assessment Score (0-5)?	List	4EnforcementConsidered	4EnforcementConsidered	4EnforcementConsidered
Which Location is the risk related to?	List	Egham&Chertsey&Walton	Egham&Chertsey&Walton	Chertsey_WTW+Source
Financial, Legal and Reputational Risk (FLR)		£101,042	£101,042	£32,101,042
Amount of penalty or fine if the risk is not mitigated?	£	101042	101042	32101042
Health & Safety Risk		£2,578,058	£2,578,058	£5,156,116
What is the consequence of a potential event/risk?	List	Major	Major	Major
Energy Efficiency Benefit				
How much energy could be saved per year?	KWh			
Unplanned Outage (AGA related)		£3,303	£3,303	£24,775
Which Location is the risk related to?	List	Affinity Water	Affinity Water	Affinity Water
If failure occurs, what is the site production capacity reduced to?	Ml/d			
How many days would it take to get production back to peak capacity?	days	4	4	30
Water Abstraction Reduction				
The population of Water Resource Zone(s) (WRZ) impacted by droughts	No. of people			
		£180,507,198	£279,424,985	£95,919,452
Likelihood of Risk Materialisation		0.01	0.01	0.01
GLOBAL STARTING RISK		£1,805,071.98	£2,794,249.85	£959,194.52
Total Risk		£5,558,516.34		

Figure 10: Business Impact of 'Do Nothing'

Root Cause Analysis

Once the risks and opportunities are clearly defined, a comprehensive root cause analysis is carried out to identify the exact source of asset failure and understand their impact on the business. The purpose is to engage relevant stakeholders with a comprehensive understanding of the assets, enabling them to collaboratively analyse and reach consensus on the root cause of the problems or opportunities. The root cause has been identified as shown in the figure 11.

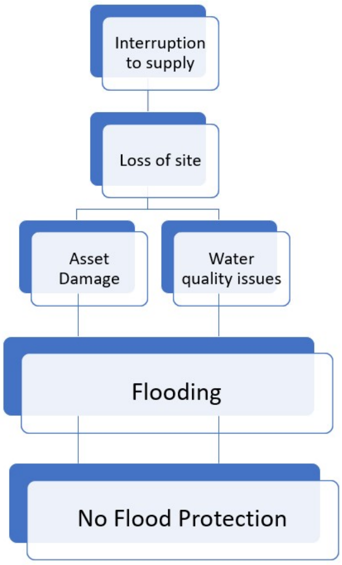


Figure 11: Root cause analysis for the flood risks

Solution Optioneering

This stage explores and identifies various unconstrained alternative solution options to manage the risk and opportunities are identified. Additionally, the Whole Life Costs (WLC) for each identified solution option are estimated using unit cost data, cost models, existing quotations, historical cost data, current supplier material, plant and labour rates, and relevant supply chain knowledge where appropriate.

The WLC is the total cost of owning and operating an asset over its lifetime. It is calculated by adding the initial capital expenditure (Capex) to the operating expenditure (Opex) over 25 years. We have identified the potential solutions and costed using available historical cost data and maintenance costs. The below options were identified as potential solutions:

a) Do Nothing

b) Optimised Flood Risk Mitigation

c) Full Flood Risk Mitigation

d) Partial Flood risk Mitigation

e) Minimum Flood Risk Mitigation

Option evaluation

In the final stage of the R&V optioneering assessment, all options are thoroughly evaluated to determine the best value solution. This is achieved by quantifying the level of risk reduction or opportunity realisation each options offers and then expressing these outputs as a risk index, which is related to their respective WLC. This comprehensive approach facilitates the selection of the most favourable solution that balances both cost and risk or opportunity considerations.

Risk reduction measures the extent to which the solution mitigates risk, while opportunity realisation measures the potential benefits and opportunities that a solution can provide. The risk reduction is calculated by subtracting the percentage of risk removed by the solution from the initial risk identified in the cost of failure assessment. Similarly, opportunity realisation is calculated by subtracting the percentage of opportunity achieved by the solution from the potential opportunities identified in the cost of failure assessment. This helps in understanding the overall impact of the solution, considering both risk mitigation and potential benefits.

Risk index is a measure of an option's cost-effectiveness. It is calculated by dividing the WLC of the option by the residual risk. It allows for comparison of different options to identify the most cost-effective one, considering both financial investment and the level of risk remaining after mitigation efforts.

A higher risk index indicates the option has a higher level of risk relative to its cost, while a lower index suggests a more favourable balance between cost and risk. The lower the risk index, the better the option is. The option with the lowest risk index is the best value option.

By comparing the cost-risk indices of different options, informed decisions can be made that account for both financial considerations and risk mitigation. This approach helps us to select options that provide best value and risk mitigation for solutions.

All the results obtained from the R&V workshops have been presented in the table below.

Table 21: Solution options and Risk Indices for all types of flood risks

Option	Solution Option Description	Capex WLC	Opex WLC	WLC	Starting Risk Value	Residual Risk / Opp	Risk Reduction / Opp Attained	Risk Index
Solution	Fluvial							
a)	Do Nothing	£0.00 m	£2.34 m	£2.34 m	£1.81 m	£1.81 m	£0.00 m	>100.00
b)	Optimised Flood Risk Mitigation	£1.38 m	£0.34 m	£1.72 m	£1.81 m	£0.36 m	£1.44 m	1.19
c)	Full Flood Risk Mitigation	£3.93 m	£0.34 m	£4.27 m	£1.81 m	£0.27 m	£1.53 m	2.78
d)	Partial Flood risk Mitigation	£3.62 m	£1.06 m	£4.68 m	£1.81 m	£0.54 m	£1.26 m	3.71
e)	Minimum Flood Risk Mitigation	£0.60 m	£1.06 m	£1.67 m	£1.81 m	£0.72 m	£1.08 m	1.54
Solution	Pluvial							
a)	Do Nothing	£0.00 m	£4.41 m	£4.41 m	£2.79 m	£2.79 m	£0.00 m	>100.00
b)	Optimised Flood Risk Mitigation	£1.53 m	£3.66 m	£5.19 m	£2.79 m	£0.56 m	£2.24 m	2.32
c)	Full Flood Risk Mitigation	£1.91 m	£4.03 m	£5.94 m	£2.79 m	£0.42 m	£2.38 m	2.5
d)	Partial Flood risk Mitigation	£1.59 m	£4.03 m	£5.62 m	£2.79 m	£0.84 m	£1.96 m	2.88
e)	Minimum Flood Risk Mitigation	£1.01 m	£4.03 m	£5.04 m	£2.79 m	£1.12 m	£1.68 m	3.01
Solution	Groundwater							
a)	Do Nothing	£0.00 m	£1.03 m	£1.03 m	£0.96 m	£0.96 m	£0.00 m	>100.00
b)	Optimised Flood Risk Mitigation	£0.26 m	£0.09 m	£0.36 m	£0.96 m	£0.19 m	£0.77 m	0.47
c)	Full Flood Risk Mitigation	£0.70 m	£0.55 m	£1.26 m	£0.96 m	£0.14 m	£0.82 m	1.54
d)	Partial Flood risk Mitigation	£0.59 m	£0.18 m	£0.78 m	£0.96 m	£0.29 m	£0.67 m	1.15
e)	Minimum Flood Risk Mitigation	£0.06 m	£0.37 m	£0.43 m	£0.96 m	£0.38 m	£0.58 m	0.75

Selected Options

We conducted criticality assessments of sites prone to flood events to determine mixed approaches and solutions to mitigate the impacts of flooding on water supply, levels of service, and water quality. After refining these assessments by cross-referencing them with the outputs of flood resilience works carried out in the past, we identified options, for flood resilience management, including a baseline option of doing nothing and alternatives with various physical works, such as enhancements, basic physical works, and blended approaches.

A summary of our Risk & Value optioneering assessment is shown on Table 22 below.

Table 22: Risk & Value Assessment Outputs summary

Risk & Value Workshop	Total WLC[36]	Average Risk Index
Scope includes assessment of: ▪ 33 no. fluvial flood risk sites ▪ 94 no. pluvial flood risk sites ▪ 15 no. groundwater flood risk sites	a) Do Nothing = £7.77m b) Optimised Flood Risk Mitigation: £7.27m c) Full Flood Risk Mitigation: £11.47m d) Partial Flood risk Mitigation: £11.08m e) Minimum Flood Risk Mitigation: £7.13m	a) Average Risk Index above 100 b) Average Risk Index 1.35 c) Average Risk Index 2.53 d) Average Risk Index 2.66 e) Average Risk Index 1.93 Recommended Option: **b) Optimised Flood Risk Mitigation**

Do Nothing, Option 0

Do Nothing: This option has an **average risk index above 100** and a **WLC of £7.77m**. The WLC of this option is the Business Impact of the 'Do Nothing' cost plus the OPEX cost over 25 years for the existing flood protection system. This option focuses on managing flood impacts by using existing provisions and procedures. This would not support our overall long-term development strategy (LTDS) ambition. Furthermore, it would not protect our customer's supply and environment.

Preferred, Best Value, Option 1

Optimised Flood Risk Mitigation: This option has the lowest **average risk index of 1.35** and a **WLC of £7.27m** among the alternatives considered. This option provides the appropriate level of physical works to mitigate water supply risks on high flood risk sites. Furthermore, this option provides the best balance of cost of delivery, achievement of ambition and feasibility to deliver as concluded by the risk & value assessments.

Least Cost Option 2

Minimum Flood Risk Mitigation: This option has an **average risk index of 1.93** and a **WLC of £7.13m**. While this option may offer some level of risk reduction for flooding, it is not the most effective or comprehensive solution available. Additionally, the option aims to provide basic physical work to mitigate the impact of flooding on high flood risk sites. Therefore, this option would not provide sufficient reliable mitigation of water supply risks.

Alternative Option 3

Partial Flood Risk Mitigation: This option has an **average risk index of 2.66** and a **WLC of £11.08m**. Comparatively, this option has the highest risk index and the second highest WLC. This option is based on providing a partial physical work to mitigate flood risks. This option would not provide enough protection to our customer's supply and limit environmental impacts.

Alternative Option 4

Full Flood Risk Mitigation: This option has **an average risk index of 2.53** and a WLC of £11.47m. Comparatively, this option has the highest WLC and the third lowest average index. This option is based on providing a blended approach of basic and extensive physical work to mitigate flood risks. This option would not provide as much value as the preferred option to achieve our LTDS ambition of best protecting our customer's supply and limit environmental impacts.

Option Assessment Approach

Economic Assessment

We have rigorously followed a robust methodology for the economic analysis using the UK HM Treasury Green Book (2020) approach as the basis for the calculations. We have developed a spreadsheet to undertake the analysis for the different options and to calculate the NPV's and benefit / cost ratios. The use of the spreadsheet enables a very flexible approach to be taken for the analysis, as we can develop several options for analysis, undertake sensitivity studies, and combine projects for analysis, as necessary.

We also use our Copperleaf system to replicate and consolidate different projects and programmes of work across the whole asset base for our PR24 submission. Copperleaf acts as the master for all of our investments and looks at the environmental and community and performance metrics across the whole investment portfolio. Copperleaf also acts as a check of some of the economic calculations.

The key features of our economic analysis approach include:

Whole life costs, benefit, and dis-benefit calculations,

Net present values calculated over a 30-year period,

Options presented in 2022/23 cost base,

Benefit valuations and metrics have followed Ofwat's methodology for performance commitments, WINEP methodology for environmental and community benefits, and supported by industry standard sources for other areas,

In a few areas, we have used our own willingness to pay valuations based upon our own research and other published research. This is either where there is no other information, e.g. low pressure, or to support sensitivity studies,

All benefit metrics and valuations are held in our Service Measure Framework,

Use of the Consumer Price Index with Housing Costs for indexation for costs and benefits,

Use of the RCV and the Spackman approach for capitalisation, and

We have depreciated the financial costs using a Weighted Average Cost of Capital (WACC) of 2.92%, which is consistent with the value used for the development of our Long-Term Delivery Strategy

In addition to the NPV assessment and the Copperleaf system, we have also used our Risk and Value process to identify the best value solution.

Cost Estimation

The cost numbers used to formulate the proposal have been taken from the historical information held by Affinity Water from actual quotations from suppliers. The costing has factored an inflation rate into consideration at the time of writing the business case (March 2023). As the inflation rate keeps on rising, there is a risk of increased costs. Therefore, the confidence rating in the costs is mid to high.

The cost estimates for previous flood civil, mechanical, and electrical works were determined using actual outturn costs from suppliers who were appointed following a full OJEU tender and procurement processes. The actual solutions are known to be efficient as the works packages underwent detailed design, solution optioneering and value engineering prior to construction.

Benefit Estimation

We have focused our benefit quantification on the use of our Service Measure Framework benefit metrics and have used the associated benefit valuations published in the Ofwat and WINEP methodologies and other sources.

We have also considered other benefits such as cost savings, additional revenue, and other performance metrics where they are applicable. We have focused on identifying and estimating the most material benefits and used these to determine the financial valuations. In general, the less material benefits are quantified or discussed. Therefore, our economic justification is intrinsically conservative by nature and simplistic and transparent in approach.

In some areas, we have had to estimate the major metrics. If these have a material impact on the analysis, then we have undertaken sensitivity studies. Where the benefits are less material, we have, where possible, qualitatively assessed the benefits rather than include them in the economic analysis.

For each benefit, we have considered the timing of the benefit realisation and duration of the benefits over time. For example, is there is any lag before the benefit will start to materialise? Is there is a phased benefit realisation? And will the benefits diminish over time? As such, we have developed a profile for each benefit over time.

Efficiency

Schemes will be prioritised following the Risk and Value methodology. There is no efficiency assumed at this stage.

We have used R&V optioneering assessments to ensure that our programme of work is prioritised to give the most benefit at the most efficient cost. We will regularly assess opportunities to potentially improve efficiency of our works and lower cost of the work required.

Assumptions Made

We have made a number of assumptions in our economic analysis. These are designed to be conservative by nature to account for the significant uncertainties that are inherent in the benefit monetisation. By making conservative assumptions and undertaking sensitivity analysis, we can be confident that the overall analysis is sufficiently robust to support the investment decisions. Our assumptions are detailed below:

Loss of Production Capacity: We have assumed that a 1 in 15 year flooding event would cause a loss of production that would impact 5% of the local population (24,940). This represents a typical risk event, although the frequency, and/or impacted population maybe different, e.g. a 1 in 25 year event impacting on 7.5 % of the population. We expect that our preferred investment will remove this risk and any lower frequency events.

We have used Ofwat's benefit valuation demand for the loss of production capacity benefit. In addition to the identified benefits in our economic assessment, we are also identified a number of other potential benefits such as asset health improvements, avoidance incident resolution costs and CRI benefits. However, these additional benefits have not been quantified or included in the economic analysis due to the high-levels of uncertainty of forecasting these low frequency, high consequence events. Only using our single benefit ensures that our analysis is conservative.

Uncertainties and Sensitivity Analysis

The most significant uncertainties are with the benefit metrics, valuations and the timing and duration of the benefits. We have used the Ofwat and WINEP valuations wherever possible and have focused our attention on the metrics and the benefit profiles.

We have made conservative estimates for when benefits will start and finish, and how they increase and decrease over time. As such, our economic analysis is inherently conservative by nature. We then consider the benefit metric for sensitivity studies as this becomes the most material uncertainty in the analysis.

Within our spreadsheet we use the goal seek function to determine the value of a metric of concern that would be required to make the scheme cost beneficial. This provides a sensitivity check on the metric and enables commentary on the reasonableness of the economic analysis. We have run sensitivity checks on all significant benefit metrics. In this instance, the key metric is the frequency of the flooding event causing loss of production to 5 % of the local population. Our analysis shows that any event worse than a 1 in 19 years event impacting 5% of the population would be cost beneficial. Alternatively a 1 in 15 year event impacting only 4% of the population would also be cost beneficial.

Carbon Assessment

To facilitate an effective and efficient process to look at the implications of our PR24 Business Cases on carbon (operational and embedded), biodiversity, including Biodiversity Net Gain and Natural Capital all Business cases were screened with relevant business cases to ascertain where there was potential for material impact on Carbon, Biodiversity or Natural Capital.

Once the potential for an impact was identified the significance associated with that impact was explored with relevant specialists and business case leads.

Figure 12: High Level Schematic of the Carbon Assessment Process

Surgery sessions were held with business case leads to set out considerations for each of the three assessment areas. Criteria to assess significance of carbon impact included:

A material increase or decrease in operational CO2 emissions and/or

An impact on capital carbon, e.g. identification of requirement for a physical build or change in capital maintenance resource use

The only carbon associated with the flood works is the embedded carbon (resulting from construction activities). These have been assessed using Affinity Water's bespoke asset carbon estimation tool which includes over 400 different carbon models covering the types of below ground and above ground assets we typically construct and operate. The outputs of the carbon assessment (as tCO2e) were fed into the cost benefit analysis for each business case option and monetised to inform the assessment of the best value options.

Embodied Carbon (kgCO2e)	Optimised Flood Risk Mitigation	Full Flood Risk Mitigation	Partial Flood Risk Mitigation	Minimum Flood Risk Mitigation
Total	5,761	8,642	4,609	2,881
Total Civil Works	5,761	8,642	4,609	2,881
Total M&E	-	-	-	-
Total ICA	-	-	-	-

Figure 13: Table Showing Carbon Tool Output for all Options

Biodiversity Net Gain (BNG)

BNG is derived from a metric created by Defra, which classifies types of habitats and their condition to give a unit score for a given site being worked on. UK Hab is the methodology that is used to classify the habitats and conditions within the metric, which is nationally used across the ecology industry.

Biodiversity Net Gain(BNG) consideration has been calculated using the assessment tool provided by the Environmental Policy & Strategies team. This applies a representative percentage value to the CapEx costs of each relevant solution option based on internal analysis. The percentage factor in this calculation varies depending on the CapEx cost in question and the BNG classification of the site. This was then verified against previous similar project BNG costs where available, to ensure that the estimated costs were not an underestimate or greatly different from what would be expected. This assessment was completed for each scheme's preferred option and other viable options that required consideration of BNG, to form part of the selection process as per the following table.

Table 23: BNG assessment

Business Case	Scheme	AMP8 Capex (£)	Special Site / Habitat	Site %	Biodiversity Capex (£)	Notes
Flooding	Enhancement	£ 2,969,620	N	1.0%	£ 29,696	Associated reinstatement works (1%)
Flooding	Base	£ 2,064,240	N	1.0%	£ 20,642	Associated reinstatement works (1%)

Third-Party Assurance and Audit Trail

All supporting documentation has been stored in the folder along with this business case.

There has been internal assurance and review through the steering group. There has been an independent audit by a consultant of the business case and the costs and benefits.

Option Assessment

Commentary on the Economic Assessment

We have undertaken a structured approach to assessing and quantifying flood risk on all sites and hence define the actual requirements to provide operational resilience against 1 in 100 year flooding events. These have been supplemented with benchmarking against our past flooding events and our work in previous AMPs.

The requirements and potential options have been developed through our Risk and Value Assessments and consolidated into different potential programmes of work and hence alternative options for investment. Our AMP8 investments primarily focus on improving the assets most vulnerable to risk in the initial phase as part of a 25-year plan to bolster resilience against extreme climate events. We have prioritised our investments to provide the best value early in the programme and will continue to learn and improve our approach to derive future best value where possible.

Each of the programme of works will ensure compliance with our obligation under Water Industry Strategic Environmental Requirements (WISER; the Flood and Water Management Act 2010 ;and the Water Resources Act 1991; and enhances our resilience against the impact of climate change on our ability to supply.

Our economic analysis has then been used to assess these programme options and select the preferred and least cost options.

The investments within AMPs 9 to 12 will mark a significant step forward in our flood resilience strategy, as we look to achieve our ambition of protecting our production sites and ensure that the supply of safe and clean water to our customers is not compromised by extreme flooding events. We have also undertaken economic analysis of the longer-term programme to check that the strategy and longer-term objective is valid.

Preferred, Best Value, Option

This option provides the appropriate level of physical works to mitigate water supply risks on our higher flood risk sites. It also provides the best balance between cost-effectiveness, achieving our objectives, and feasibility in delivering the desired outcomes. Furthermore, it will reduce the risk of loss of production during both moderate and extreme flood events. This suggests that it aligns well with the organisation's goals of ensuring water supply reliability and resilience in the face of potential challenges.

We believe that the benefits will be larger than modelled but understand that the quantification of these benefits are inherently difficult. The option also has the lowest average risk index which is indicative of its comparative best value. Our sensitivity analysis shows that realistic risk events would be mitigated by the investment and show a cost benefit.

The benefits derived from the preferred option are considered more favourable in relation to the associated costs.

Least Cost Option

The least cost option only provides basic protection to prioritised flood prone sites. It does not provide sufficient dependable mitigation of water supply risks. We would have a significant number of customers that are still at risk of interruptions to supply, poor pressures or experiencing water quality issues.

In essence, the proposed programme of work for AMP8 is the least amount of works that are necessary to realise any meaningful benefit and have been targeted at the highest risk areas.

Alternative Option 1

This option is based on blended approach of basic and extensive flooding resilience measures. It involves increasing flood mitigation levels beyond the necessary level to enhance resilience against flooding. This option involves more environmental intensive and carbon generating physical works. This option would, therefore, impacts on our ambition to safeguard the environment.

Considering these factors, this alternative option would not deliver best value compared to the preferred option in terms of protecting the customers' water supplies and minimising environmental impacts. For these reasons and the inherent uncertainties in the analysis, it is prudent to invest at the lower level in AMP8 and consider the potential additional works in future AMPs.

Justification of the Preferred Option

This business case supports Affinity Water's outcome to minimise disruption to our customers and communities. The preferred option enables Affinity Water to achieve:

Resilience against the impacts of flooding up to 2050

Safeguard customer water supplies during flood events

Comply with regulatory and legislative obligations

The preferred option meets our long-term ambition to improve the resilience of our production sites from the impacts of extreme flooding events. The economic assessment and Risk and Value assessments have indicated that the preferred option is the most cost-effective and best value choice for customers. The project will primarily focus on improving the assets most vulnerable to risk in AMP8 whilst being part of a continuous longer-term plan to strengthen resilience against the consequences of extreme flooding events.

The project's benefits have been estimated conservatively, with a clear indication of cost-benefit advantages resulting from reducing the impact of flooding events on production capacity. However, there are additional unquantified benefits that may be realised as the project progresses, and better estimates of different benefit metrics become available. These benefits will be reviewed accordingly and used to plan future programmes of work.

Our preferred option is also our least cost option and offers best overall value to customers; balancing the need to address the highest and most pertinent risks against the impact on customers' bills. We have prioritised and selected the most cost beneficial elements of work that address the highest risk areas. The alternative option of doing more in the AMP period was discounted due to its higher capital expenditure; higher impact on carbon and the environment; and because of the uncertainties in assessing the risks.

Delivery Considerations

Related Projects

The following programmes will have either have a direct or indirect impact on the flooding business case planned outcomes:

- Estates
- Non-Infrastructure
- SEMD
- Supply 2050
- WINEP

We plan on liaising with stakeholder groups to monitor developments in these areas, to seek opportunities and manage any conflicts.

Lessons Learnt

Our experience in delivering various flood defence works in previous AMPs provides us with confidence in identifying and delivering the flood defence works in AMP8. We are familiar with current flood management technologies and design best practices. This positions us to meet our long-term objectives.

Pre-planning and early engagement with contractors, supply chain partners, as well as internal and external stakeholders, is crucial for ensuring smooth project delivery. By involving these parties from the early stages, we will benefit from their expertise, insights, and collaboration. This approach will help us to address concerns and optimise project outcomes.

Our Sustainability Reductions projects have been identified as one of the areas that may introduce a new potential groundwater flood risk. As such, we have included an on-going process to assess the flooding risks that this project may introduce as part of our flooding strategy.

Delivery Risk Management

The identified delivery risks and proposed mitigation associated with our flood resilience long-term ambitions are as follows:

Delivery Risk	Mitigations
Conflicting priorities/ Operational Constraints	▪ Early engagement with Capital delivery and other internal stakeholders ▪ Advance liaison with Customer delivery team ▪ Schedule work with consideration to other programmes and seasonal constraints
Cost Accuracy	▪ Use of best available data from previous projects ▪ Application of detailed planning and forecasting methodology
Flood Risk Data Accuracy	▪ Use of latest flooding model available ▪ A system put in place to monitor any changes in flood risk data

Delivery Risk	Mitigations
Contractor Resources	▪ Use of framework contractors ▪ Early engagement with contractors
Change in Government Expectations or Change in Legal Requirements	▪ Stay updated with changes in regulations and make necessary adjustments ▪ Implement controls and monitoring systems to ensure compliance.
Materials Costs and Availability	▪ Identify alternative suppliers or vendors to mitigate dependency risks. ▪ Maintain strong relationships with key suppliers and regularly assess their performance.
Climate Change	▪ Adaptive strategy to climate change ▪ System in place to monitor climate change data and legislation

Further detail regarding how we have ensured the deliverability of our full investment portfolio is provided within AFW 32 Deliverability of our Plans.

Monitoring and Reporting of Benefits

Progress with our flood resilience plans, along with our planned benefits, shall be monitored regularly at programme boards. Individual flood resilience projects shall be measured against time, quality and costs controls as well as their risks to planned scope and benefit realisation.

Benefits will be quantified by the number of completed flood resilience projects against our production sites, development of local flood contingency plans, and successful achievement of emergency planning exercises.

Supporting Information

Information supporting this business case is as flows:

- CBA Flood Alleviation
- PR09 Consultancy Framework, Flood Risk Assessment
- Flood Resilience Feasibility Study
- Assessment of Works to Mitigate Flood Risk at Surface Water Sites
- Surface Water Flood Risk Assessment
- Groundwater Flooding Report 2014
- Environmental Agency published flood maps
- Resilience assessment tool

Affinity Water

Resilience: Single Points of Failure

July 2023

Contents

Summary

Our long-term strategy is to ensure that our network and treatment facilities are resilient to a range of external risks including the impacts of climate change, pandemics etc. A first step in this process is to ensure that our asset health is sufficient to continue to operate and deliver service to customers. As such, we have developed a base investment programme to continue to maintain and improve the health of our existing assets and address the external risks that we face.

As part of this we have started to fully adopt Ofwat's Operational Resilience Framework and incorporate the principles and methods into our asset and corporate planning processes. We have already improved our asset health reporting, data capture and analysis, and we intend to make further significant improvements in this area in the future to improve how we identify and prioritise our future investments for resilience. In AMP6 we started a specific programme to address the high and medium frequency events as part of our base investments. This programme continued through AMP7 and will continue through AMP8.

Our on-going base investment programme not only protects against existing climate-related risks and other risks, the activities also provide additional protection for the future and increasing climate change risk. As and when we strengthen and maintain our network we also provide some future protection. However, this does not fully protect the whole network against future climate change and emerging third-party risks.

Our resilience enhancement investments, for AMP8, will focus on protecting the areas of our network that are prone to increasing climate change and emerging third-party impacts on our ability to supply water. This includes identifying and addressing the weakest areas of our network, or what we call the single points of failure (SPOFs) that are prone to climate change and third-party impacts. This investment programme aligns and integrates with our network, WRMP and Long-Term Delivery strategies.

We appreciate that it is difficult to forecast climate change any other risks and so our approach and investment has been conservative. We believe that the best way to mitigate against these risks is with an on-going long-term programme of work that focuses on the more immediate and highest risk areas and learns and adapts over time.

We have consistently found that the provision of safe, secure, supply of water is a high priority for customers. When considering resilience in this context, customers' generally focus on reducing bursts and leakage. Bursts can have a significant impact on customer satisfaction as they can lead to disruption, traffic congestion and pollution. Reducing leakage is consistently mentioned in any engagement that we do, and always features in the upper quartile of priorities. As such, there is strong support for investing to address resilience issues, particularly by proactively reducing the impacts of bursts on customers.

Our enhancement investments for resilience in AMP8 focuses on addressing the impacts of climate change and emerging third-party impacts by undertaking a programme of work to identify, prioritise and resolve the low frequency, high consequence, single points of failure.

By investing in the enhancement of our infrastructure to address the single points of failure, we can strengthen our resilience, reduce operational risks, and ensure a consistent water supply to our communities. This strategic enhancement aligns with the goals and priorities of our customers and Ofwat, allowing us to create a sustainable and adaptable water infrastructure capable of meeting future demands.

Our proposed programme is cost beneficial; it supports our wider and longer-term strategies; it is supported by customers; and it offers best value to customers by balancing risk to services against customer affordability.

Project Details

AMP8 Spend	2025-26	2026-27	2027-28	2028-29	2029-30	Total
Capex (£m)	0.51	0.77	1.29	1.54	1.03	**5.14**
Opex (£m)	0.00	0.00	0.00	0.00	0.00	**0.00**
Totex (£m)	0.51	0.77	1.29	1.54	1.03	**5.14**
Drivers						
100%	Resilience					
Benefits						
Water Supply Interruptions (property mins)						
Economic Analysis						
NPV Costs (£m) (2025-55)		**4.1**	NPV Benefits (£m)(2025-55)			**11.0**
NPV (£m) (2025-55)		**6.9**	Benefit / Cost Ratio			**2.7**

Six Capitals					
Natural	Social	Financial	Manufact.	Human	Intellectual
	★ ★ ★	★	★ ★		★

Project Description

We have identified a number of Single Points of Failures across our network that are the most vulnerable to climate change driven weather events and emerging third-party impacts. By strengthening these points, we can reduce the impact of any interruptions on customers.

We have utilised the 4R model, Figure 1, and Ofwat's Operational Resilience Framework principles to provide identify and develop solutions for the adequate level of resilience.

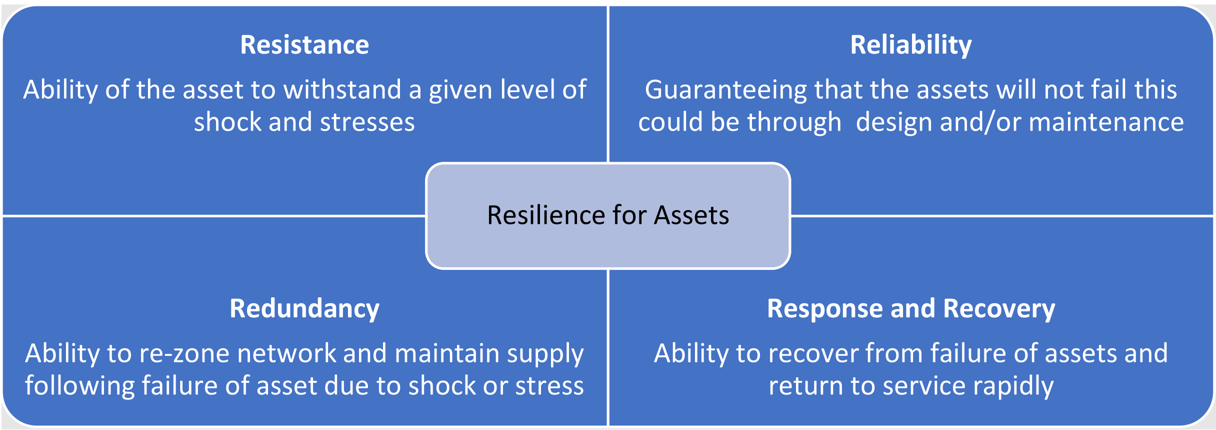


Figure 1: 4R model - Resilience for assets

The steps we have used to develop our options are:

- Identify the shocks and stresses that our assets face from climate change
- Define the Single Point of Failures
- Identify the potential Single Point of Failures
- Assess the criticality of the assets
- Assess the current level of resilience for the assets vs their ability to meet our Performance Commitments
- Promote schemes that meets the enhancement driver of improving resilience to the low probability, high consequence climate change and third-party impacts
- Validate the schemes against the Asset Resilience Tool

Project Development

Definition of SPOF

We have defined Single Points of Failures as the weak points that have a low likelihood of failure but high consequences for customers, aligning with the Ofwat driver "Improving resilience to low probability, high consequence, events[1]".

SPOF vulnerabilities can arise when critical components, such as trunk mains or key infrastructure, are compromised, resulting in service interruptions and therefore inconvenience for customers. The consequences can be particularly severe when a SPOF impacts many properties, potentially leaving thousands of customers without access to clean water. These disruptions can affect various aspects of daily life, such as household chores, personal hygiene and business operations that rely on a consistent and reliable water supply.

Despite implementing the most efficient operational response, there will still be unavoidable disruptions to the supply that affect thousands of customers, resulting in water shortages, and the broader community will face road closures and restricted movement.

To prioritise the schemes, the identified SPOFs have been divided in two categories: Category A and B. The specifics and criteria for each category are elaborated upon in the Allocation of Costs section. This categorisation allows for a systematic approach in determining the importance and potential impact of each SPOF.

[1] Improving resilience to low probability high consequence events link

Baseline Assessment

Table 1 below shows the top 20 shocks and stresses that have been generated from our resilience risk workshops.

Ageing infrastructure	Supply chain failure	Terrorist attack	State collapse or crisis
Leakage	Fire events	Catchment/site contamination event	Demographic change
Extreme weather	Climate change (incl. drought and sea level rise)	Extreme river pollution	Cyber attack
Asset failure	Pandemic	Digital revolution	Extreme reservoir pollution
Abstraction licence changes	Aircraft crash	Failure of climate change mitigation and adaptation	Increased criticality of National infrastructure

Table 1: Top 20 shocks and stresses generated from Operational Resilience Workshop

Assessment of Critical Assets

To calculate the number of customers impacted by a failure, each of the pipe elements were combined into suitable isolation groups (cohorts) by grouping pipes with identical consequences together. Critical Link Analysis (CLA) was performed on each of these sections using the InfoWorks Water Supply (WS)Pro software. The results of this analysis forecasted the number of customers affected by a shutdown of each group and the number of customers that would be isolated in that group. This was then mapped backed to each of the pipe elements. Our entire network was divided into 389,802 cohort.

The CLA results from the model shows that approximately 0.35% of our entire network length are SPOFs for more than 2,000 properties. If 1,358 out of the 389,802 cohorts were to fail, it would result in the loss of water supply for more than 2,000 properties.

Problem Statement and Stated Need / Driver

The Role of On-going Capital Maintenance

Our on-going base programmes, such as pressure management and mains renewals, already play a crucial role in mitigating risks associated with water mains in poor state and reducing the likelihood of failures. These initiatives form an integral part of our infrastructure improvement efforts and contribute significantly to improving the overall resilience of our water network. However, whilst pressure management and mains renewals address the overall infrastructure condition, they may not adequately tackle the specific risks posed by SPOFs.

Our Long-Term Base SPOFs Programme

During AMP6, we developed the trunk main mitigation report. This was an hydraulic assessment of the impact of trunk main failures on the network and the options to mitigate the impacts. The outcomes of the assessment included the number of customers affected and the storage implications for each section of the trunk main with each section evaluated from valve to valve. The report not only helped to identify SPOFs and vulnerabilities within the network, it also included the available mitigation measures. If mitigations were absent, the report recommended capital solutions to mitigate the impacts.

As a result, we have developed a long-term programme to address the high and medium risk SPOFs as part of our base investments, and hence strengthen the resilience of our network.

In AMP6 and AMP7, we have successfully implemented interventions for a number of our high and medium probability SPOFs. The solutions included renewals and new assets such as cross-connections, dual cells for treated water storage and secondary booster pumps. Some of the schemes already implemented include: a cross-connection installed off the 600mm main on High Street in Luton; at Windmill Hill Reservoir in Hitchin a 250mm PE main was installed to mitigate the SPOF on the existing 8-inch main; a PRV cross connection was installed in Birdsfoot Lane, Luton, and a valve was installed on the 8-inch main at Bell Farm (South East). Collectively, these measures have enhanced our network's resilience and translates to 24,000 properties being mitigated.

In the current AMP7, using the trunk main mitigation report and our Risk and Value process, we are delivering three SPOFs schemes and will continue address the top priority high and medium likelihood SPOFs using our Risk and Value methodology. The first scheme involves the installation of four PRVs at Folkestone Low. The second scheme is the installation of a second inlet in Park Avenue, Southall area. The final intervention aims to reinstate an abandoned main to address a SPOF in Murray Road, Chertsey. Collectively, these schemes will enhance the network's resilience and translates to 14,501 properties being mitigated.

In AMP8, we will continue to invest in our base long-term programme, and address the high and medium likelihood SPOFs.

Addressing Climate Change and Third-Party Impacted SPOFs

Whilst our existing infrastructure currently meets operational demands, it is imperative to proactively prepare for the challenges posed by climate change, emerging third-party impacts, and the associated increased likelihood of failures. These risks present a distinct challenge that require a dedicated investment.

Our on-going base investment programme not only protects against existing climate-related risks and other risks, the activities also provide additional protection for the future and increasing climate change risk. As and when we strengthen and maintain our network we also provide future protection. However, this does not fully protect the whole network against future climate change and emerging third-party risks.

We have built upon our AMP6 work, to identify those SPOFs not covered by our base investments, that are characterised by their low likelihood and high consequences that are being impacted by climate change and new third-party events. We have used our Risk and Value process and improved our modelling to identify these risks and how best to mitigate them.

This enhancement investment will address the low likelihood, and high consequence SPOFs, i.e. those impacted by climate change. These are events where one identified shock or stress can cause a major disruption to customers' lives, either due to lengthy (greater than 24 hours) interruption to the supply or affecting customers' ability to circulate, resulting from the closure of major Critical National Infrastructure (CNI) roads or railways.

As evidenced in the climate change section, the increasing frequency of extreme weather events and bursts underscores the progressive and pressing need to address the arising vulnerabilities in our network. Climate change heightens the vulnerability of our water network, necessitating proactive measures to mitigate risks and ensure on-going system resilience.

Climate Change Forecasting

It is predicted that climate change is likely to significantly impact the water industry. Analysis was undertaken using Affinity Water burst date and average groundwater level data by month from January 1990 to December 2019. Using this data, it is possible to observe a correlation between the increased variation in groundwater levels and variation in bursts rates.

There is measurable increase in the monthly burst rate delta and the monthly groundwater levels (GWL) delta. More granular work was undertaken to better understand the reasons for these observations. The graphs in figures 8 to 10 display a trend of the average monthly burst rate, for condition driven failures only, and monthly delta change in GWL by month for each decade.

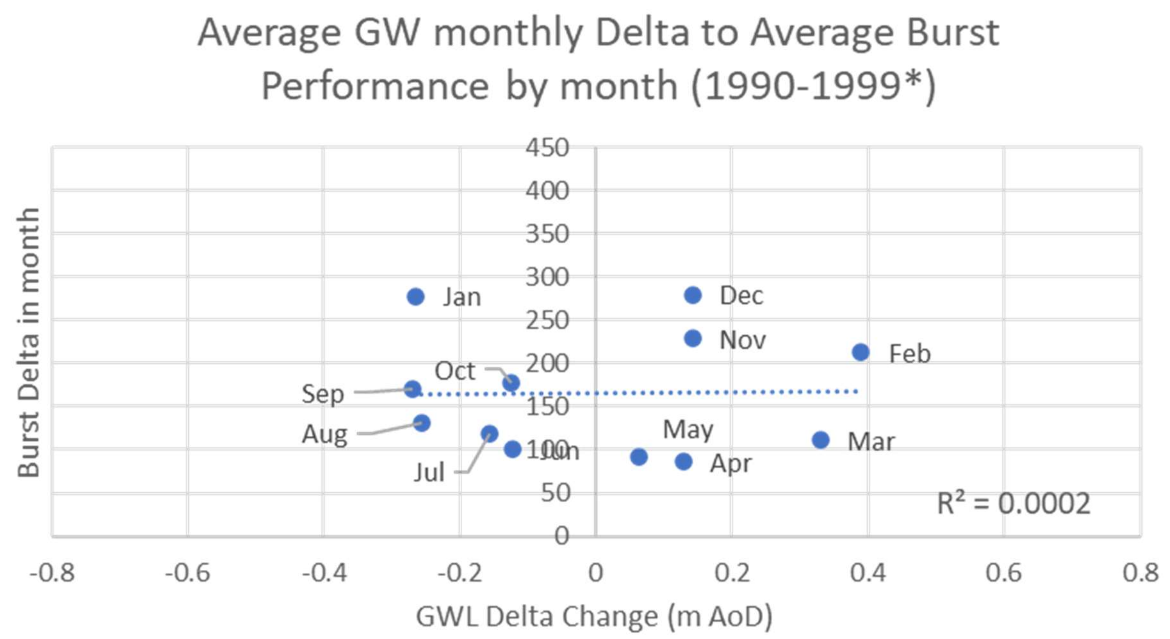


Figure 8: 1990s GWL to average burst correlation

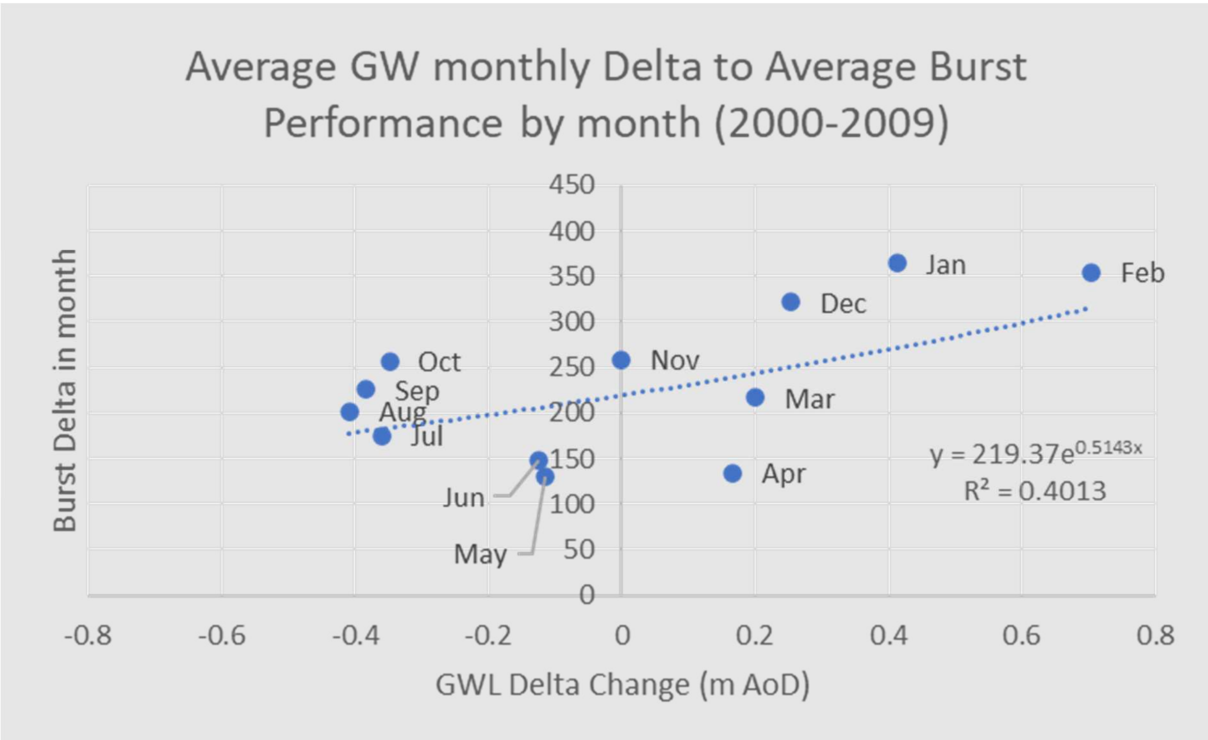


Figure 9: 2000s GWL to average burst correlation

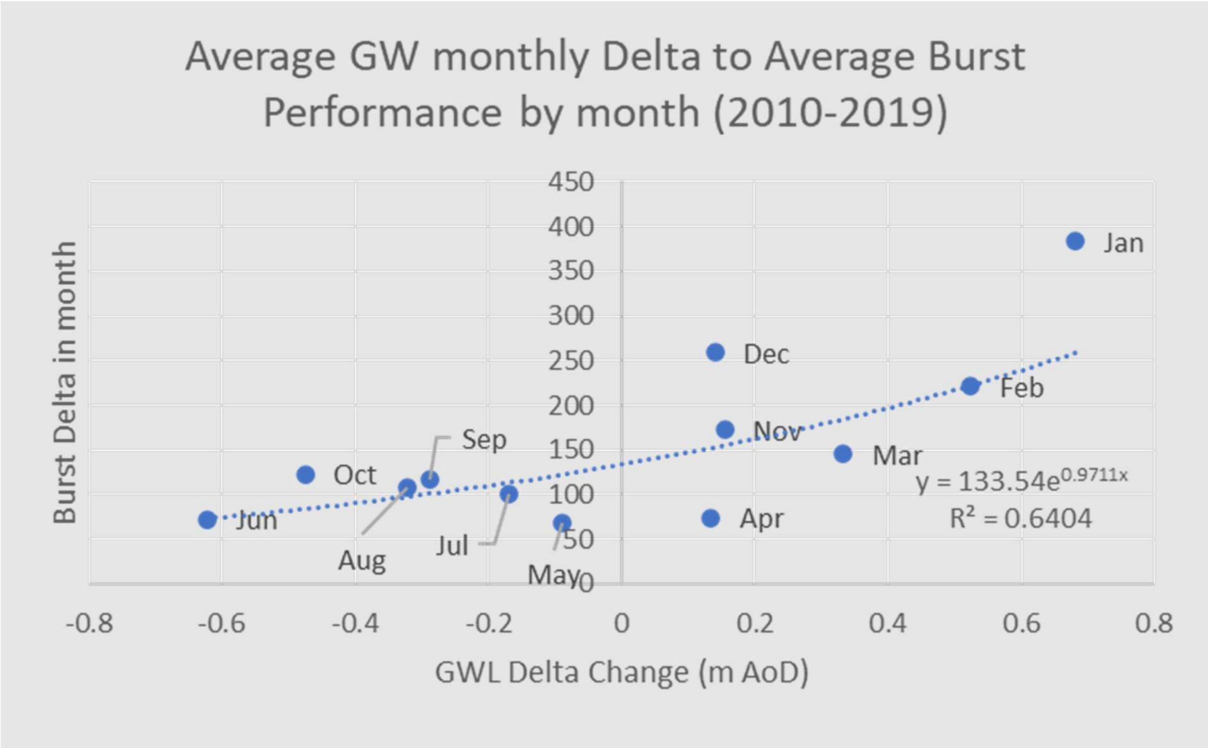


Figure 10: 2010s GWL to average burst correlation

It can be observed that whilst there is little correlation in the 1990s data set, the correlation is increasingly stronger in the 2000s and the 2010s. This appears to be due to consistently drier periods in the summer months (negative changes in GWL) and more consistently wetter periods in winters (positive changes in GWL). There is measurable increase in the monthly burst rate delta and the monthly GWL delta.

When the relationship is applied to the GWL sequence for the WRSE central scenario, the average mains bursts per annum increases over the 2025 to 2055 horizon:

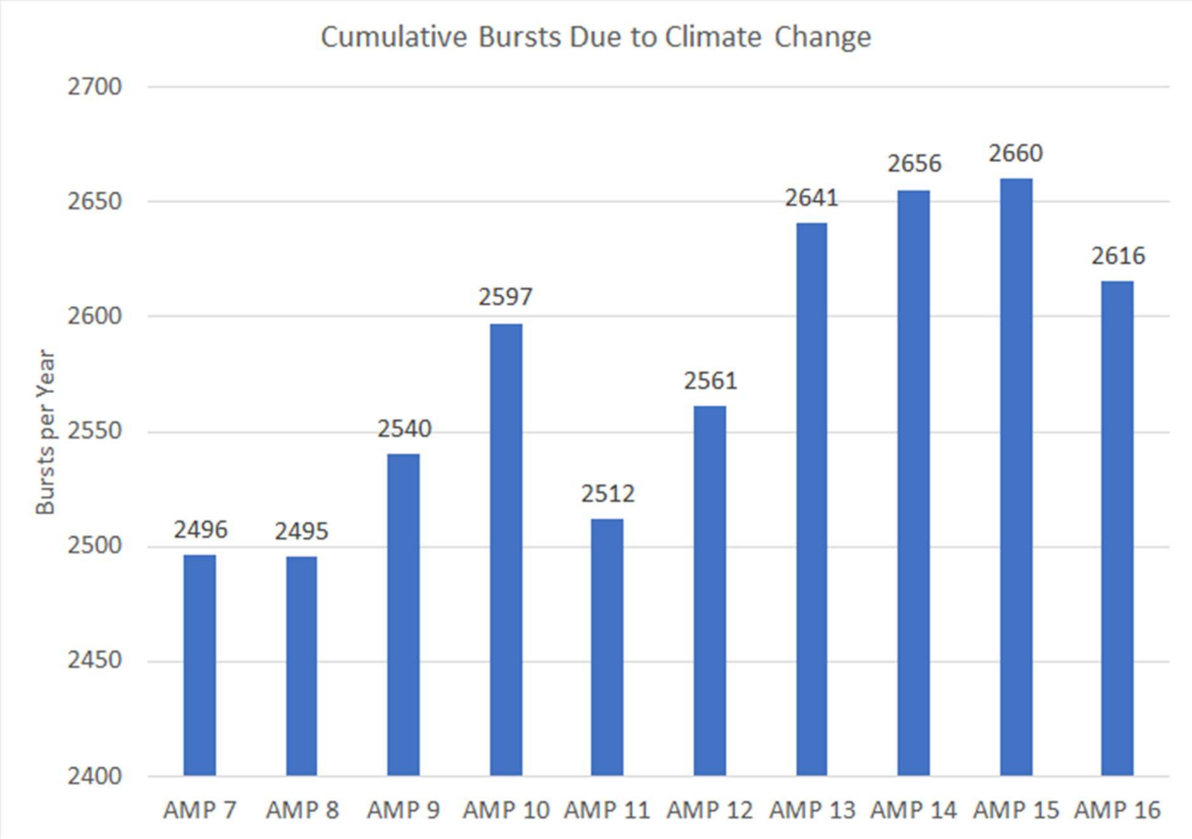


Figure 11: Forward projection of average annual burst rate due to Climate Change

The results show that, over a 35-year period, climate change would account for an additional 160 bursts from the end of AMP7. The variability from AMP-to-AMP (leading to decreases in AMP11 & 12) are a function of the probabilistic nature of the method used. The methodology uses ground water level data derived from the stochastic forward projection used in the WRMP, which entails a certain level of uncertainty. The main increasing trend remains across the time horizon.

Climate change influences groundwater levels due to altered precipitation patterns and increased evaporation rates. This can lead to changes in ground stability, potentially accelerating ground movements. Additionally, these shifts in moisture and groundwater can increase the likelihood of sinkholes in vulnerable areas which have wider impact on the community. While the direct link between climate change and earthquakes is more complex, changes in water loading from melting ice or reservoir fluctuations might influence stress on fault lines. In summary, climate change has the potential to significantly impact various geophysical processes, including groundwater levels, ground movements, sinkholes, and earthquakes. However, all of these hazards and stresses are outside AW management control and cannot be covered by other enhancement areas.

Image 1 below shows a massive sinkhole that was 10 metres deep and 20 metres wide.It appeared on a residential street in St Albans in September 2015[2]. This sinkhole was located 400 metres away from one of our service reservoirs at Stonecross site.

[2] Massive sinkhole opens up on street in St Albans - BBC News

Experts believe the root cause of the sinkhole was related to historical land use and ground conditions.

[redacted]

These sinkholes, likely to occur more frequently due to climate change, can damage both distribution mains and key strategic trunk mains. They can also disrupt power supply, affecting motorised valves and pumps, and damage telecommunications cables associated with sensor alarms related to our assets. Consequently, enhancing the network and addressing SPOFs will be crucial to mitigate the effects that climate change will have on our network. However, all these hazards and stresses are outside AW management control and cannot be covered by other enhancement areas.

Risks, Issues and Requirements

The SPOF investment requirements are linked to our Performance Commitments. Our Network Strategy sets our ambition for AMP8 to achieve a reduction of 30% in the water supply interruptions performance measure (5 minutes per property, as stated in our Network Strategy) by the end of AMP8.

The presence of SPOFs in a water network can give rise to several risks and significantly impact customers in various aspects of daily life. These risks are primary divided into two categories: risk to the community and risk to the environment.

Risk to the Community

SPOFs can lead to interruptions in the water supply, causing service disruptions for customers and affecting household chores, personal hygiene and business operations that rely on a consistent and reliable water supply. Additionally, they can result in decreased water pressure throughout the network, further hindering daily activities and operations. Moreover, SPOFs can compromise water quality, potentially stemming from inadequate treatment processes, ingress, discolouration and other factors, raising concerns regarding the safety and suitability of the water provided.

Repairing or replacing failed components or systems affected by SPOFs may take time, especially when complex infrastructure or specialised equipment is involved. Furthermore, due to the need to avoid customer impact, shutting down the main is often not possible, requiring live repairs whenever possible. However, these failures still cause disruptions, including road closures, increased traffic and the potential for flooding. These disruptions can affect travel routes, cause property damage and pose safety hazards. Furthermore, businesses and the local economy can experience operational disruptions and financial losses.

To minimise these disruptions and inconveniences, proactive measures such as prompt repairs and proactive maintenance play a crucial role in addressing and mitigating the risks associated with SPOFs main failures. In addition, SPOFs can have financial implications for customers, such as the need to purchase bottled water and potential losses for businesses, including restaurants or schools, impacted by the service disruptions. It is also worth noting that there are some critical customers in our network, like those requiring dialysis, who are particularly reliant on a consistent water supply. Therefore, it is essential for water utilities to prioritise identifying and addressing SPOFs to ensure a reliable and resilient water supply system.

Environmental Risks

SPOFs, by their nature, often pertain to large diameter mains which transport a significant amount of water. Challenges in shutting down these mains can result in delays in repairs, leading to the loss of substantial amounts of this vital resource, further necessitating increased abstraction from ground and surface water sources. If a SPOF is located in strategic locations such as under railways or major motorways, the required shutdowns or repair activities could lead to increased CO2 emissions due to traffic congestion.

Direct Procurement Contracts (DPC)

Ofwat has determined that DPC will apply by default for all discrete projects above a threshold of £200m whole life Totex. Ofwat's technical discreteness guidance (April 2023) also states "Strategic Resource Options (SRO) proceeding via the RAPID gated process have also been required to assess the suitability of delivering the SRO via DPC." Due to its size, this programme is not suitable for the Direct Procurement for Customers.

Research, Pilots and Technology Development

Managing resilience requires a good understanding of risk. Since AMP6 we have been developing our approaches to better understand the risks associated with the SPOFs and climate change. As part of this, we have undertaken a number of wider initiatives.

NUAR (National Underground Asset Register)

Affinity Water, in collaboration with other utility partners, is building upon the Cabinet Office's National Underground Asset Register. This digital map, which details underground pipes and cables, is set to revolutionise the way we install, maintain, operate, and repair our buried infrastructure. It aims to minimise the risk of trunk mains being damaged by third-party work and to reduce the probability of an event occurring. We have shared information from our SPOFs criticality link analysis to ensure other utilities exercise extra caution when working near our most critical mains.

Designer Liner

Designer Liner is built on the Breakthrough 2 initiative of Ofwat's Innovation Fund. Water companies, led by Yorkshire Water, will collaborate to develop a lining solution that is fit for a 21st century water network and complements other technologies, like smart networks and devices. Affinity Water is partnering on this innovative project. For areas with site complications, we can deploy solutions like Designer Liner.

The need for enhanced durability and reliability in water infrastructure is evident as, water pipes are often underground and at mercy of the elements; meaning that they are prone to leaks and bursts. Repairing and replacing water pipes is costly, so one way to reduce issues and prolong the lifespan of a pipe is to line it and add an extra layer of protection. Pipe lining is 50% cheaper than more traditional methods, it generates less carbon and reduces disruption for customers because there is less need to dig up the road. While this approach can reduce the likelihood of certain issues, it may not diminish the impact should those issues arise.

Smart Network and Digital Twins

Good data is fundamental to good decision-making. Utilities often struggle to effectively use their data because it is isolated in disconnected IT solutions, spreadsheets and paper records. To address this, digital twins are a powerful strategy that many water companies are beginning to adopt. A digital twin is a virtual representation of a physical asset, process or system. For a water utility, a digital twin can be continuously updated with virtual operational data from supervisory control and data acquisition (SCADA) systems, sensors, meters and other measured sources, creating a real-time model that can be used in operations.

A digital twin dynamically changes based on the data that it receives, allowing it to mature and yield valuable information that is not generated by a traditional static model and that capability can drive business decisions. The concept of a digital twin can be used at different scales, from an individual component like a pump or valve, to a subsystem like a water treatment plant or other facility, to an entire utility network. Digital twins can be useful in every phase of the asset lifecycle, from planning and design, to construction, to operations and maintenance. Also, digital twins can be useful to many different types of people, including engineers and designers; operators; and a range of stakeholders, including individuals inside the utility such as executives outside the utility such as the public. Smart networks and digital twins can help locate and repair small leaks before they become a burst, subsequently reducing the probability and consequence of failure.

New live repair techniques will reduce the response time to repair a burst and subsequently reduce the consequences of the burst. Affinity Water is project managing the playbook for the user cases to be implemented under the Safe Smart System OFWAT innovation project.

Customer Engagement

Customer Engagement

We have undertaken extensive engagement with our customers to build a detailed understanding of their priorities and reflected these in this business case. For more detail on our customer engagement see AFW04 What Customers and Stakeholders Want.

The insight and testing of our business plan with customers have been integral to its development. The voice of the customer is used throughout the process to shape and challenge the plan across its development and at each stage.

The triangulated customer insight has shaped and informed the overall strategy, informing each business case and the solution options within them. The triangulated customer valuations have populated the Service Measures Framework used to prioritise investments.

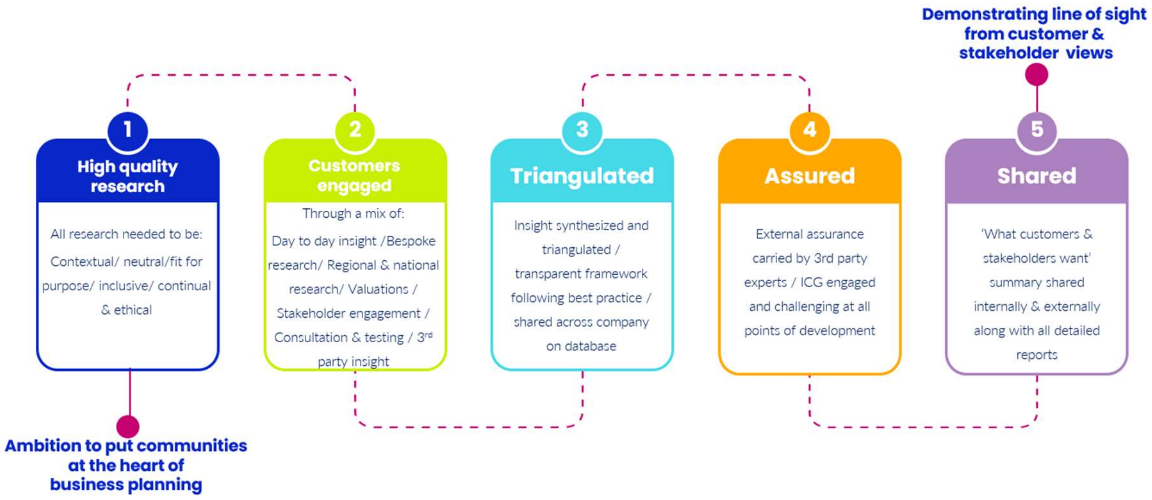


Figure 6: Customer Engagement Work

The consultation and testing phases of engagement allowed us to 'check-back' with customers and stakeholders to ensure we had the right mix and balance and test overall acceptability and affordability of the business plan. We have shared our assured findings both across the business and publicly to ensure transparency.

Evidence of Customer Preferences

Our proposed SPOF investment is classified as resilience. Our customers do not automatically identify resilience as an area of high concern, especially relating external factors to the impact of delivering of a secure supply of water. They more naturally think of bursts or leakage when they think about resilient supplies.

The link between climate change and increased resilience risk is also not usually considered. However, when we dig deeper there is an assumption we would plan ahead, and with operational and asset type risks being seen as the most logical to plan for with a level of mitigation against more environmental risks.

PCD and Customer Protection

Customers will be protected through a Price Control Deliverable (PCD) metric. We propose to use a metric based upon the reduction of the risk of significant interruptions to supply resulting from severe weather events and how many properties will not be impacted. We will fund each scheme based on a unit cost allowance for mitigating properties, with a target of completing a maximum number of properties by 31st March 2030. If the company ends up delivering fewer mitigated properties than the maximum target, any cost sharing will be calculated proportionately to the target cost.

Strategy Development

All of our enhancement cases have been developed as part of our integrated investment portfolio that takes the first steps of our Long Term Delivery Strategy and achieving our ambitions as laid out in AFW03 Strategic Direction Statement.

Long-term Delivery Strategy Alignment

This programme is aligned with our WRMP to ensure that we have sufficient water supply in the network and can efficiently distribute water across the entire network.

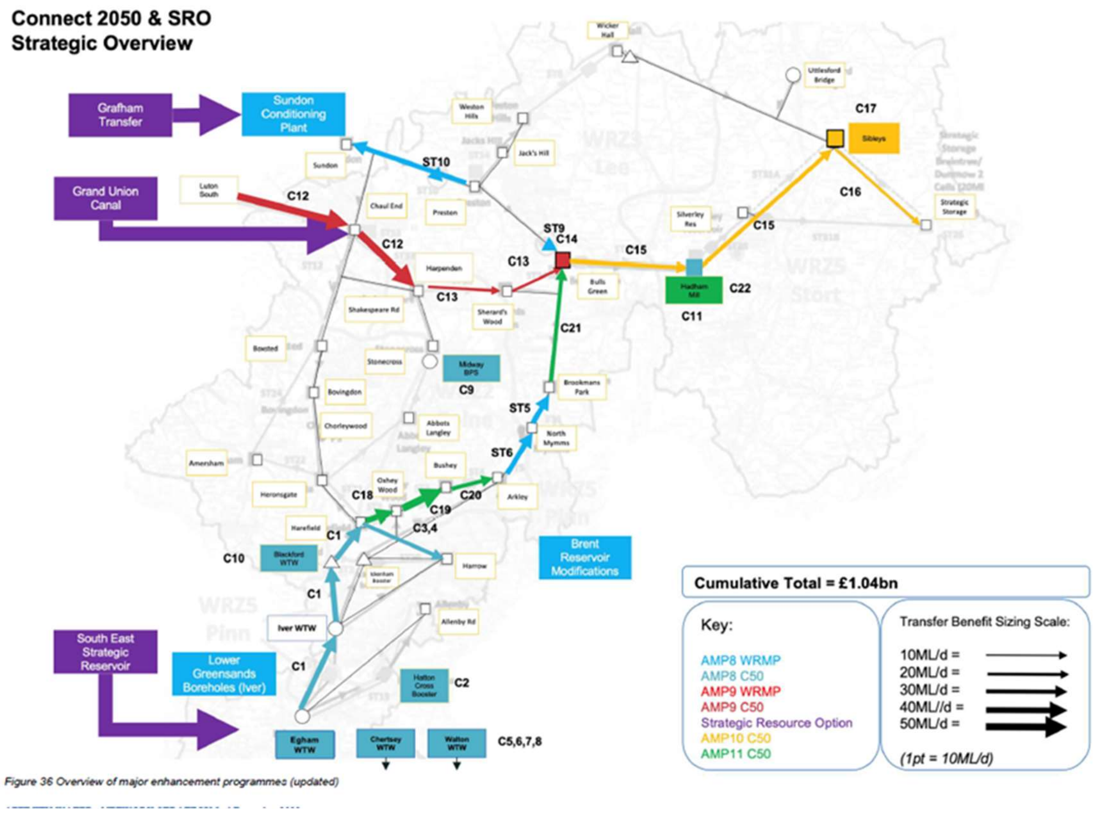


Figure 7: Connect 2050 Strategy

This programme aligns with our network and treatment strategies. The absence of these enhancement SPOFs interventions would compromise the network strategy by reducing reliability, increasing risks and impeding the ability to provide uninterrupted service to customers over the longer term. Implementing these SPOFs interventions is crucial to enhance the resilience, performance and long-term sustainability of the network.

The network reinforcements capital solutions to be delivered in AMP8 will be "no regrets" schemes accounting for our long-term 2050 ambition to supply to customers greater than 3 hours by 2050 (Table 2).

PC	AMP8	AMP9	AMP10	AMP11	AMP12	AMP 8 – AMP12 cumulative
Water Supply Interruptions improvement driven **by SPOFs enhancement investments (s)**	**7**	**10**	**8**	**5**	**4**	**34**

Table 2: Water supply interruption ambition as stated in Network Strategy

The reinforcements are sized to meet the supply demand balance in up to a 1 in 500 years drought scenario and peak summer demand.

The programme supports key performance targets, aiming to:

- Reduce disruption to the community
- Reduce interruption to supply
- Provide high quality drinking water

The following programmes or activities should be considered:

- **Carbon and biodiversity impacts:** For schemes that may have carbon and biodiversity impacts, assessments will be conducted and mitigation methods prioritised if they do not compromise the risk reduction objectives of the scheme.
- **Long-term delivery strategy:** Connect 2050 serves as the foundation for our transfer of water strategy (Figure 7), which has the potential to impact or create opportunities within the programme. Therefore, maintaining effective communication with the relevant workstreams will help mitigate any potential conflicts and ensure a smooth implementation of the strategy.

Single Point of Failure Strategy

The steps used to develop the business care have been:

- Identify shocks and stress that Affinity Water assets face
- Define Single Point of Failures
- Identify all Single Point of Failures that have the potential to generate interruption to supply
- Assess criticality of the assets
- Assess the current level of resilience for the assets against ability to meet our ambition for AMP8 and 2050
- Promote schemes that provide the optimum balance between risk, cost and performance
- Validate the schemes against the Asset Resilience Tool. This tool is designed to help us identify, understand and actively manage the risks to resilience that we face. It ensures that all these risks are approached consistently. Furthermore, it

provides insights into how each risk impacts outcomes. The tool also guides investment decision-making and supports long-term adaptive planning, enabling us to assess the best options to manage these risks. The Asset Resilience tool assessment for SPOFs can be found in Appendix 1.

We have rigorously followed a robust methodology to identify the high-risk enhancement SPOFs. We have developed a spreadsheet with data from CLA produced in 2021, which provides a breakdown of the number of customers impacted for each section of main from valve to valve or connection. This data has been cross-referenced with the risks reported on ARM and trunk main reports. The following example in Table 3 pertains to one of the trunk mains identified in the CLA. In the event of a burst occurring in any of these seven sections of TM reference (ST18 and ST69), there will be 13,615 properties without water and currently no re-zone is available for them.

Due to the hydraulics characteristics of our network, sections with different trunk main numbers will have a similar impact, particularly at connection points and trunk mains supplying other trunk mains.

LENGTH	MATERIAL	NOMINALDIA	DATELAID	TRUNKMAINN	HDZ	Properties Affected
2.13	CI/SI	16"	01/01/1964	ST18	Letchworth	13615
53.32	CI/SI	16"	01/01/1962	ST69	Letchworth	13615
12.27	CI/SI	16"	01/01/1962	ST69	Letchworth	13615
4.01	CI/SI	16"	01/01/1962	ST69	Letchworth	13615
768.50	CI	16"	01/01/1962	ST18	Letchworth	13615
25.32	CI	16"	01/01/1962	ST18	Letchworth	13615
1.03	CI	16"	01/01/1962	ST18	Letchworth	13615

Table 3:Trunk Main Example

As part of the customer engagement, our delivery colleagues provided us with a list of mains that they identified as SPOFs due the operational risk associated with implementing the re-zone or engineering difficulties involved in the repair process, which may require a longer outage. These are also reported on ARM. All of them have been reviewed and if they met the criteria, were also incorporated on the SPOFs list. For example, TP45 is crossing the A2, which is a critical national infrastructure and can cause customer supply disruption as well as significant disruption regionally or nationally due to expected outage longevity.

There are currently 19 sections of trunk main that represent the highest priority SPOFs risks (Figure 12) and in the event of a failure that can cause interruption to supply for large number of properties without an available re-zone. Furthermore, there are up to 73 sections of trunk main that require a trunk main mitigation report to confirm if there is a mitigation measure in the event of a failure of the asset or if a capital solution is required.

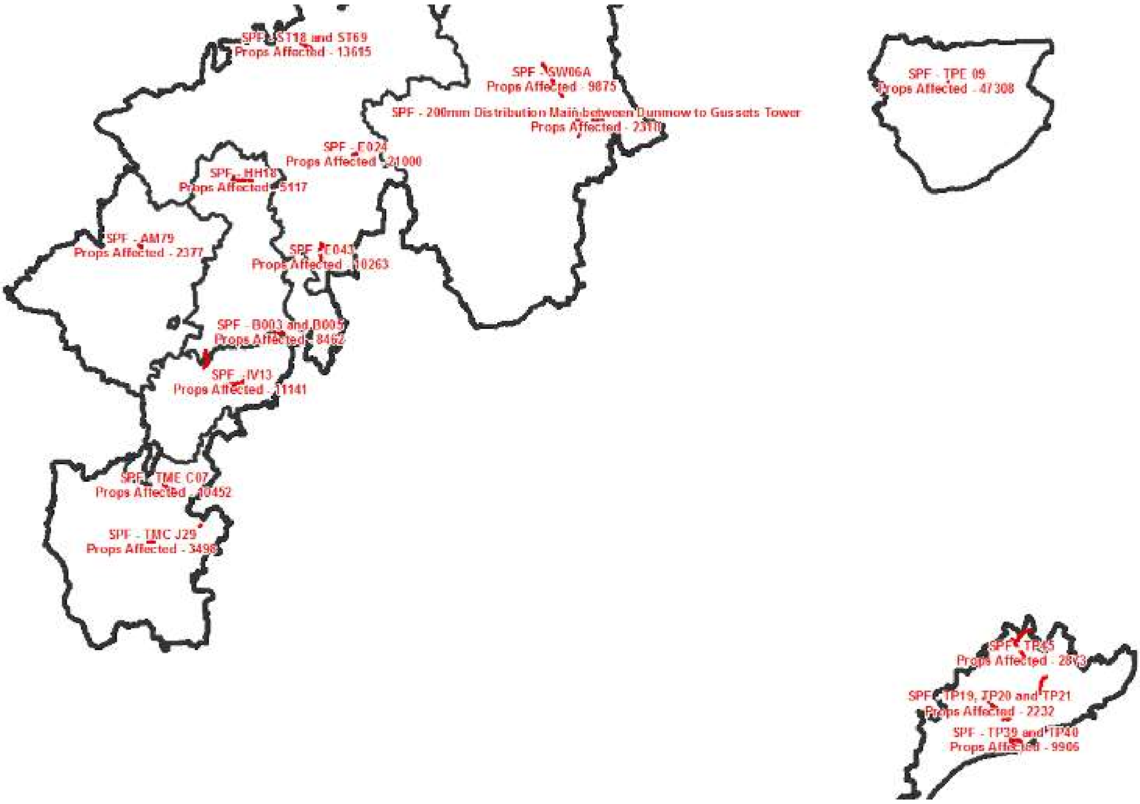


Figure 12 shows the 19 sections of TM that represent the highest priority SPOFs risks

Table 4 below summaries the sections of trunk main, including their length, the properties affected, the cost to eliminate the SPOFs risk and the risk index.

Table 4: List of the highest priority SPOFs:

TM REFERENCE	Category	Comments	PR 24 Cost	Risk Index	Properties affected	Length(m)	Burst/annum	Risk/annum	Risk Reduction after works	Risk Index PR24 Cost
TPE 09	B	Outlet of Horsley Cross at Brett(ID 3396)	£30,618	0.028157961	58398	286.589	0.042145441	£268,324	£268,324	0.00228217
TP37,38 and TP40	B	18'' near the Eurotunnel (ID 2860).	£70,000	0.002754381	9205	3444.125	0.506488971	£508,281	£508,281	0.002754381
IV13	B	36'' Between Iver and Harrow Reservoir(ID 2810)	£635,000	0.016021827	11141	18170.458	2.672126176	£3,245,572	£3,245,572	0.003913023
R018 ,R025,R020A ,R021 ,R023	B	18''Either Side of Joel Street, at the boundary between Clay Lane and Harrow(ID 2814)	£280,000	0.006654663	23526	2231.067	0.328098088	£841,515	£841,515	0.006654663
TP29,TP30 and TP36	B	At Cherry Gardens, South East(ID 2845)	£300,000	0.010729185	9903	3522.22	0.517973529	£559,222	£559,222	0.010729185
HH18	B	315mm at the Outlet of Shakespeare Road Reservoir at Harpenden(ID 2808 and 2809)	£143,930	0.015961446	5117	2268.244	0.333565294	£186,083	£186,083	0.015469484
TMW H06,TMW H12	B	15'' and 250mm at Walton HDZ(ID 2857)	£302,874	0.01852725	7971	2574.397	0.378587794	£328,995	£328,995	0.018412079
TP42 and TP41	B	Chalksole to Lydden Hil at SE(ID 2862)	£1,047,262	0.025736426	7448	9331.536	1.372284706	£1,114,279	£1,114,279	0.018797118
E043	B	24'' downstream Brookman Park Tower, at Swanley Bar(ID3401)	£1,738,725	0.068044082	10263	3172.937	0.466608382	£522,080	£522,080	0.066607611
TP39	B	600mm DI at Folkestone low,nearby the Eurotunnel terminal(ID 2511)	£280,000	0.093190523	9906	378.37	0.055642647	£60,092	£60,092	0.093190523
TMC-JS29	B	8'' PVC main at the Inlet of DMA 0040,at Chertsey	£109,285	0.042139094	3498	319.262	0.046950294	£17,905	£17,905	0.122073742
ST18 and ST 69	B	16'' At Baldock(ID 3115)	£1,204,654	0.126052447	13615	866.582	0.127438529	£189,160	£189,160	0.127368957
TP45,TP60	A	Old Wooton Res to Aylesham(ID2870)	£2,138,025	0.105319397	2873	6460.866	0.950127353	£297,596	£297,596	0.143686231
TP19,TP20 and TP21	B	250mm at Ottinge Pumping Station(ID 2534)	£2,225,725	0.245002537	2232	6985.874	1.027334412	£249,986	£249,986	0.178067762
TME C04,TME C07,TME C08	B	12'' PVC at Ashford(Egham Low), ID 2817	£3,234,452	0.223268525	10452	1633.307	0.240192206	£273,696	£273,696	0.236353629
B003,B005	B	16'' Broadfield Avenue and Uphill Drive at Clay Lane(ID 3048)	£2,111,372	0.165457299	8462	1294.848	0.190418824	£175,668	£175,668	0.240381854
TP22	B	Paddlesworth Reservoir to Aerodrome Road (ID 2840)	£1,602,018	0.370558546	4786	1067.521	0.156988382	£81,913	£81,913	0.391153364
E024	A	Crossing a National Infrastructure.27" Bulls Green to Hadham Mill Thames Link Crossing.. ID 3113	£1,065,260	0.570270193	21000	100	0.014705882	£33,668	£33,668	0.632797944
AM77 and AM79	B	300mm at DMA 8505 at Bovingdon(ID 2805)	£160,889	1.334367473	2377	85.591	0.012586912	£3,262	£3,262	0.986499478

For each section of the trunk main, the risk is calculated by multiplying the likelihood with the consequence. In this assessment, the consequence is determined by the number of properties affected if a specific section of the main fails. The likelihood element is based on the number of bursts per annum as a company-level target divided by the total length of mains in the entire network. The likelihood is then multiplied by the length of each section of the trunk main to calculate the overall risk. It should be noted that because the SPOF is an asset that has a low likelihood of failure occurring but high consequence to customers, for this assessment, all sections of the trunk main have been assumed to have the same probability of failure. To convert the risk into monetary units, the calculated risk is multiplied by the cost for failure per property. This method ensures that the interventions to solve the SPOFs deliver the best value proposition by offering an optimal balance between risk, mitigation and performance. Finally, the risk index is obtained by dividing the cost of the intervention by the risk reduction achieved over a duration of 50 years (the asset intervention is assumed to last 50 years). Additionally, for each section of the trunk main, a category A or B designation is assigned to determine if it is considered a critical national infrastructure.

$$Risk = (Number\ of\ properties\ affected \times (Number\ of\ burst \div Length\ of\ the\ entire\ network\ ) \times Length\ of\ the\ section) \times Cost\ for\ failure\ per\ property \times 50\ years$$

This method allows for prioritising interventions based on the trunk main's risk, cost and performance. By assessing the risks associated with each section and considering the consequences, likelihood of failure and criticality, interventions can be focused on the highest-risk areas. The goal is to achieve an optimal balance between reducing risks, managing costs and maintaining system performance. This approach ensures that resources are allocated effectively to mitigate failures and minimise impacts, resulting in efficient risk management and improved overall performance.

In Table 4, it can be seen that to solve the highest priority SPOFs risks that are currently confirmed on the network, up to £20.6m needs to be spent. To determine the economic feasibility of the project, various funding scenarios were considered. These scenarios ranged from 0% to 100% of the required funds, allowing for an evaluation of the project's financial viability under different funding levels. Additionally, two specific scenarios were analysed: one considering only category A schemes and another considering only category B schemes. This comprehensive assessment provides valuable insights into the financial implications of each funding option and aids in making informed decisions about the optimal approach for the business case.

Interdependency with Other Programmes of Work

Some of the SPOFs have synergies with other projects or programmes of works that need to be aligned.

Connect 2050: For example TM reference (R018,R025,R021,R023) connects our Clay Lane and Harrow systems via Joel Street PRV, which serves as a SPOFs for up to 23,526 properties. As part of the Ickenham project, a new pipeline will be commissioned from Ickenham to Oxhey reservoir and will pass nearby the existing SPOFs. Therefore, there is an opportunity to interconnect both mains and reduce the SPOFs to below to 1000 properties (customer impact can be reduced by 96%). Subsequently the cost of this scheme is only £280k; however, the solution cannot be implemented until the strategic main is commissioned.

Low Pressure: The optioneering process will also consider the interdependency between SPOFs schemes and low pressure, recognising both the potential risks and the benefits associated with this relationship.

Adaptive Strategy

The Network Strategy was issued by PA Consulting in December 2022 and was developed in two phases: Phase 1: Optioneering and Phase 2: Preferred Option Selection & Development. The strategy concludes that the preferred network strategy option, Option 19, has a 25-year Totex of £5bn (inclusive of treatment no regrets scope). Option 19 will achieve Affinity Water's ambitions (as agreed with Affinity Water Network Strategy Steering Group) which can be seen in Table 5 below.

PC	AMP8	AMP9	AMP10	AMP11	AMP12
Water supply interruptions (Minutes)	5	4.5	3.8	3.0	2.7
Mains Bursts	2250	2025	1841	1656	1491
CRI Score (Index)	1.8	1.5	1.2	1.1	1
Leakage(ML/d)	124.7	116	107	104	90.6

Table 5: Water Supply Interruption ambition as stated in network strategy

Selected Options

This project defines the investment for the next AMP. However, this investment is part of a longer-term programme of work that will constitute a step change to improve the resilience of our network over the next 25 years against climate change for low likelihood – high consequence events.

We have prioritised our investments to provide the best value early in the programme and will continue to learn and improve our approach to derive future best value where possible, low regret approach. We have also undertaken economic analysis of the longer-term programme to check that the strategy and longer-term objective is valid. Schemes have been prioritised based on current network performance, build rate on development sites and network performance post development.

As highlighted in the previous section and in Table 4, addressing the highest priority SPOFs risks currently identified in the network requires an expenditure of up to £20.6m. To evaluate the economic feasibility of the initiative, we examined various funding scenarios, ranging from 0% to 100%. Both the residual risk and the cost were determined for each scheme. For example, in the 25% funding scenario, we can address 9 of the schemes, with the residual risk, funding, and number of properties mitigated amounting to the cumulative totals for these schemes. This methodology is applied consistently across all scenarios. Comprehensive details are available in Appendix 1.

Do Nothing, Option 0

In the "do nothing" scenario, there is no allocation for SPOFs. The residual risk will be £8.9m per annum which translates to 222,173 properties being affected.

As mentioned in the proposed definition for the SPOF section, the "do nothing" scenario would give rise to several risks, including the potential for SPOF vulnerabilities to cause service interruptions and inconvenience for customers. These consequences can be particularly severe when a SPOF impacts numerous properties, potentially leaving thousands without access to clean water.

Option 1, Least Cost Option and Alternative Options 1 to 4

Based on the comprehensive economic assessment carried out, it is evident that investing in SPOF mitigation through Options 1 to alternative Option 4 yields significant benefits. The assessment reveals that implementing any of these schemes would result in positive outcomes, although with varying levels of advantage. It is worth noting that schemes catering to a larger customer base offer greater benefits, highlighting the importance of prioritising solutions that maximise customer coverage. Consequently, the funds required to invest in these SPOF mitigation measures are justified by the substantial benefits they bring, with a focus on optimising customer service and satisfaction.

Preferred, least cost, Option 1

Allocating 25% of the funding (£5.1m) will result in a risk reduction of £6.8m per annum and the residual risk will be £2.1m per annum (RI=0.015), which translates to 74,311properties mitigated. This option is the preferred option as we are taking a cautious approach limiting impact on customers' bills while monitoring the full impact of climate change.

Alternative Option 1

Implementing 100% of the programme at a cost of £20.6m provides the optimum balance between the 4R. This approach ensures that the interventions to solve the SPOFs deliver the best value proposition by offering an optimal balance between risk, mitigation and performance and will result in a risk reduction of £8.9m per annum. (RI=0.046), which translates to 222,173 properties mitigated. However, this option was discounted as the impact on customers' bills was deemed too high.

Alternative Option 2

Allocating 75% of the funding (£14.9m) will result in a risk reduction of £8.6m per annum, with a residual risk of £0.3 m per annum (RI=0.035), which translates to 191,778 properties mitigated.

Alternative Option 3

Allocating 50% of the funding (£10.4m) will lead to a risk reduction of £8.1m per annum, with a residual risk of £0.8m per annum (RI=0.026), which translates to 172,864 properties mitigated.

Alternative Option 4

By solely undertaking category A schemes, a funding of £2.7m is required. This approach will result in a risk reduction of £0.3m per annum, while the residual risk will amount to £8.6m per annum (RI=0.15), which translates to 23,873 properties mitigated.

Alternative Option 5

By exclusively focusing on category B schemes, a funding of £17.9m is required. Implementing this approach will lead to a risk reduction of £8.6m per annum, with a residual risk of £0.3m per annum (RI=0.04), which translates to 198,300 properties mitigated.

Least CAPEX Cost Option 6

Reactive response to all incidents using the restoration team. Reactive response may not always be feasible and can cause disruptions to customers due to the logistical challenges involved. Additionally, this approach would result in increased Opex cost.

Least CAPEX Cost Option 7

Zero-operation restoration, live bypasses, or under-pressure repair may not always be feasible, particularly on trunk mains, due to the high flow and pressures to which they are subjected. Employing bypasses and line stops can also increase operational expenditure and potentially prolong the repair duration, resulting in interruptions to the water supply for customers during the works.

Alternative Options

As an alternative to the options previously discussed, we might choose to await an asset's failure and then respond reactively using the current technologies available. Line stops, bypasses and overland riders can be employed to prevent disruption to the supply. However, their suitability is constrained by factors such as the pipe's material, size, depth and the requirements of bespoke delivery labour.

Moreover, we have the option of deploying pressure tankers. These portable assets, whilst invaluable, have a limited capacity and need to be matched to the specific size of the incident. For larger-scale disruptions, multiple pressure tankers would be necessary. All these reactive solutions carry inherent risks.

In summary, whilst employing available technologies to react to asset failures provides a method to handle infrastructure disruptions, it presents significant challenges. Delays in restoring service, the potential for property damage, increased operational costs and the associated expenses are all pressing considerations. Striking the right balance between proactive and reactive strategies is vital in mitigating these challenges.

Option Assessment Approach

We have consistently proposed best value solutions using rigorous optioneering. For more detail on our approach is provided within AFW08 Our Investment Development Process.

Economic Assessment

We have rigorously followed a robust methodology for the economic analysis using the UK HM Treasury Green Book (2020) approach as the basis for the calculations. We have developed a spreadsheet to undertake the analysis for the different options and to calculate the NPVs and benefit / cost ratios. The use of the spreadsheet enables a very flexible approach to be taken for the analysis, as we can develop several options for analysis, undertake sensitivity studies and combine projects for analysis as necessary.

We also use our Copperleaf system to replicate and consolidate different projects and programmes of work across the whole asset base for our PR24 submission. Copperleaf acts as the master for all of our investments and looks at the environmental and community and performance metrics across the whole investment portfolio. Copperleaf also acts as a check of some of the economic calculations.

The key features of our economic analysis approach include:

- Whole life costs, benefit and dis-benefit calculations
- Net present values calculated over a 30-year period
- Options presented in 2022/23 cost base
- Benefit valuations and metrics have followed Ofwat’s methodology for performance commitments, WINEP methodology for environmental and community benefits and supported by industry standard sources for other areas
- In a few areas we have used our own willingness to pay valuations based upon our own research and other published research. This is where there is no other information, e.g. low pressure, to support sensitivity studies

- All benefit metrics and valuations are held in our Service Measure Framework
- Use of the Consumer Price Index with Housing Costs for indexation for costs and benefits
- Use of the RCV and the Spackman approach for capitalisation
- We have depreciated the financial costs using a Weighted Average Cost of Capital (WACC) of 2.92%, which is consistent with the value used for the development of our Long-Term Delivery Strategy

Cost Estimation

We have used our Unit Cost Library (UCL) to determine the cost for each scheme. Many different factors such as urbanicity, main surface and size were considered in determining the costs. These cost models have been third-party assured as part of our PR24 process. In addition to this, the cost models were verified against our current framework rate as we deliver this type of work on a daily basis and this means that our cost models are mature and accurate.

Our Asset Delivery colleagues have also helped to capture additional cost models, particularly those costs that relate to difficult and/or unique engineering areas. Our costs have been verified against the BGA delivery framework rates to ensure confidence in our estimates.

Our UCL also includes the cost of fittings, excluding control valves such as Pressure Reduction Valves or Pressure Sustaining Valves. To determine the costs related to engineering difficulties and control valves, reliable costs from similar and recently completed schemes have been used as references. Our UCL is a comprehensive tool for estimating costs of proposed schemes. It considers the Below Ground Asset (BGA) delivery framework rates, current supplies, overheads, risks and indirect costs. Overheads account for indirect expenses and risks address unexpected costs. Indirect costs beyond overheads are also factored in. The UCL facilitates informed decision-making, resource allocation and financial planning within the AMP. Additionally, yearly inflation updates ensure accuracy. In summary, our UCL streamlines cost estimation and enhances financial management for the AMP.

It is important to note that these cost estimates are at a high-level, as we have not yet conducted detailed surveys, utility checks, traffic management assessments or confirmed the feasibility aspects. This preliminary cost analysis serves as a broad overview of potential costs at this stage of the project. In certain schemes that involve engineering challenges like crossing a major river or railway line, additional costs have been incorporated to account for these difficulties based on our previous experience of addressing such issues. The cost models confidence grade for this programme is considered to be Medium.

We control costs by using the agreed framework cost, where the framework partners have been selected via a competitive tendering process for their competence to undertake the required works and for presenting the most cost-effective options. Each scheme goes through the Asset Planning process where cost and benefits are scrutinised and framework partner cost are benchmarked against cost models.

Benefit Estimation

We have focused our benefit quantification on the use of our Service Measure Framework benefit metrics based on the agreed performance commitments and have used the associated benefit valuations published in the Ofwat methodology.

We have also considered other benefits such as cost savings, additional revenue and other performance metrics where they are applicable. We have focused on identifying and estimating the most material benefits and used these to determine the financial valuations. In general, the less material benefits are quantified or discussed. Therefore, our economic justification is intrinsically conservative by nature, while simplistic and transparent in approach.

In some areas, we have had to estimate the major metrics such as the time required to restore supply to customers and the length of the disruption to the customers. If these have a material impact on the analysis, then we have undertaken sensitivity studies. Where the benefits are less material, we have, where possible, qualitatively assessed the benefits rather than include them in the economic analysis.

For each benefit, we have considered the timing of the benefit realisation and duration of the benefits over time. For example, is there is any lag before the benefit will start to materialise? Is there is a phased benefit realisation? And will the benefits diminish over time? As such, we have developed a profile for each benefit over time.

This project has also been through a detailed Risk and Value assessment. This has helped identify the risks addressed by the project and hence support the quantification of the benefits.

The benefits will be estimated using PR24 cost models, estimate solution life (40 years for Civils and 20 years for M&E) and valuations from the Service Measure Framework where appropriate to estimate the risks cost per annum.

Carbon, Biodiversity and Natural Capital Assessments

To facilitate an effective and efficient process to look at the implications of the PR24 Business Cases on carbon (operational and embedded), biodiversity, including Biodiversity Net Gain and Natural Capital, all Business cases have been screened with relevant business case leads to ascertain where there was potential for material impact on Carbon, Biodiversity or Natural Capital. Once the potential for an impact was identified the significance associated with that impact was explored with relevant specialists and business case leads.

Surgery sessions were held with business case leads to set out considerations for each of the three assessment areas. Criteria to assess significance of carbon impact included:

- A material increase or decrease in operational CO_2 emissions and/or
- An impact on capital carbon, e.g. identification of requirement for a physical build or change in capital maintenance resource use
-

Both the embedded carbon (resulting from construction activities) and operational carbon (resulting from energy and chemical use) were assessed using Affinity Water's bespoke asset carbon estimation tool which includes over 400 different carbon models covering the types of below ground and above ground assets we typically construct and operate. The outputs of the carbon assessment (as tCO_2e) were fed into the cost benefit analysis for each business case option and monetised to inform assessment of the best value options.

Figure 13: Business Case Screening

Within the framework of our SPOF Business Case, the rigorous carbon assessments and biodiversity evaluations are more than just supplementary processes; they form an integral part of our decision-making strategy. As we seek solutions for potential vulnerabilities in our water supply network, it is imperative to recognise that each intervention or infrastructure change has environmental ramifications. By holistically integrating carbon footprint insights and biodiversity considerations, we are not just addressing immediate network vulnerabilities but also ensuring that these solutions are sustainable, both in terms of environmental impact and long-term operational viability. This holistic perspective ensures our SPOF strategy is aligned with broader organisational commitments to sustainability, thus adding layers of responsibility and foresight to our infrastructural decisions.

Efficiency

We have used our Risk and Value methodology to ensure that our programme of work is prioritised to give the most benefit at the most efficient cost. Each of the different schemes have been assessed and prioritised. We have used information on our current network performance; current building levels on development sites; and network performance forecast for post-development changes.

Further efficiencies will be sought during the delivery stage through our delivery Risk and Value review and through project synergies and our procurement activities.

Assumptions Made

We have made a number of assumptions in our economic analysis. These are designed to be conservative by nature to account for the significant uncertainties that are inherent in the benefit monetisation. By making conservative assumptions and undertaking sensitivity analysis, we can be confident that the overall analysis is sufficiently robust to support the investment decisions. Our assumptions are detailed below:

- We have assessed the risks associated with each SPOF and then developed options to mitigate the risks. The risks are quantified and then overall risk reduction is determined for each option. We have used these risk reductions in our economic analysis
- We have estimated the overall frequency of the infrequent events that cause extreme supply interruptions to be 1 in 100 years
- We have assumed that the impact will be a prolonged supply interruption lasting between 2 and 7 days, based on the average duration of cut out repair of large diameter mains
- We have assumed that the benefits will only be realised in AMP9 and beyond and will remain at a constant rate for the assessment period
- Climate change will increase urbanisation and the likelihood of third-party damages on the network due to greater level of activity in the vicinity of our assets
- All the SPOFs have been identified in the CLA review
- No newly created SPOFs
- All key shocks and stresses have been identified
- In some instances, conducting live repairs on trunk mains is not always feasible, leading to the need for bypasses and line stops to ensure uninterrupted water supply to customers. Examination of our GIS burst records over the last 5 years indicates that clamps were utilised for live repairs approximately 37% of the time. However, in cases of SPOFs where customer impact is a concern, implementing line stops and bypasses emerge as the only viable option for securing water supply. By addressing SPOFs risks, we estimate that it would be possible to isolate the main without requiring a bypass or line stop, potentially resulting in cost savings of up to £0.7m annually based on the burst rate for 5.1m funds.

Uncertainties and Sensitivity Analysis

The most significant uncertainties in the economic analysis related to the benefit metrics, valuations and the timing and duration of the benefits. We have utilised the valuations provided by Ofwat wherever possible and have focused our attention on the metrics and the benefit profiles.

We have made conservative estimates for when benefits will start and finish, and how they increase and decrease over time. As such, our economic analysis is inherently conservative by nature. We then consider the benefit metric for sensitivity studies as this becomes the most material uncertainty in the analysis.

Within our spreadsheet we employ the goal seek function to ascertain the value of a concerning metric that would be required to make the scheme cost beneficial. This provides a sensitivity check on the metric and enables commentary on the reasonableness of the economic analysis. We have run sensitivity checks on all significant benefit metrics.

In order to mitigate against project uncertainties and to avoid potential double-counting we have integrated all of our infrastructure business cases with our over-arching network strategy to identify synergies and delivery efficiencies.

Mitigate against uncertainty and avoid potential double counting the following actions are undertaken:

- Collaboration all infrastructure business cases
- Aligned with network strategy
- Risk scoring in line with audited corporate standard
- Weekly cross-functional strategic infrastructure meetings

Third Party Assurance and Audit Trail

The business case has been reviewed internally within Affinity Water through the Network Strategy steering group and externally by QASR. Three revision cycles have been completed with senior leadership. During cycle one, an initial review of all investment needs was conducted. In cycle two, a detailed examination of the business cases was conducted, including the background issues of the programme, a comparison with the previous AMPs, an assessment of the needs and how the business case is linked to the performance commitments. Dependencies with other programmes of work were also identified and further steps were agreed upon. The objective of cycle three was to assess the risks associated with not securing the desired level of funding, ensure alignment with the Long-Term Delivery Strategy, address changes from cycle two, evaluate the business impact and cost efficiencies of each option and ensure that all business cases meet the required quality and ambition.

In addition to the above, an independent third-party assurance audit has been carried out by: Atkins for our PR24 data table and business case, and KPMG for our Resilience LTDS.

Option Assessment

Commentary on the Economic Assessment

Our primary analysis has been to assess the preferred, least cost and some alternative options. We have supplemented this with an additional assessment to understand the sensitivity of the key assumption on the proportion of the extreme supply interruption improvements that will be realised as a result of our activities.

Estimating the risks and how best to mitigate these is complex. We have, therefore, undertaken economic assessments in each area to select the best value solutions and optimise the level of investment in AMP8. Our economic analysis builds upon our Risk and Value workshops that undertake in-depth assessments to better understand the resilience risks and how best, and when, to mitigate these.

Preferred, Best Value, Option

Our economic analysis has shown that the preferred option is the best overall value option. It is also the Least Cost option as this was found to be best value. It is highly cost beneficial and the activities will provide significant performance benefits, as part of our wider and longer-term programme of work to improve our network resilience.

The economic assessment forecasts a positive NPV of £5.2m with an excellent benefit / cost ratio of 2.7. The benefit / cost ratio is the highest of the options that we have considered.

The analysis has shown that focusing on the Least Cost option, i.e. the highest risk SPOFs will provide the best value for customers. Our strategy has been to focus on these areas in AMP8 and consider the alternative options of additional works in future AMPs as part of our longer-term strategy. This offers the best balance to customers of addressing the service risks against increasing customers' bills.

The economic assessment has focused on the benefit of reducing the frequency and consequence of extreme interruption to supply events resulting from the weaker areas of our network. We have also identified that this work will strengthen the network in many other areas and hence provide benefits in the following areas:

- Reduced risk of boil notice events
- Reduced risk of hosepipe bans
- Lower incident response costs
- Improvements in reputation, particularly relating to major supply incidents
- Traffic disruptions
- Lower numbers of unplanned mains repairs
- Minimise the risk of water quality issues associated with the depletion of reservoirs, ingress of water into the network system and the occurrence of discoloured water.

We have assumed a risk frequency of 1 in 100 years across all options. We have calculated that our preferred option would still be cost beneficial if the risk frequency was less than 1 in 800 years. This provides a high-level of confidence that the scheme will be cost beneficial.

Least cost Option

The least cost option represents the minimal spend on proactive enhanced SPOF removal. This option has the lowest Capex of all the options considered. Our economic analysis has shown that this offers the best cost benefit for customers and has therefore been selected as our preferred option.

Alternative Options

Although these options are all cost beneficial, none of these offer the same level of cost benefit as the Least Cost / Preferred Option. This is because the different programmes have been prioritised to mitigate the highest risk areas first. The analysis also shows that the programme should consider additional investments in future AMPs, and that we should further improve our understanding of these risks.

Meeting Affinity Water's Outcomes

This business case supports our objectives to deliver service more efficiently and to increase the resilience of the network over the longer term. The preferred option enables us to achieve our stated ambition in the short-term; namely the AMP8 performance commitments relating to supply interruptions and low pressures.

The project also supports the Long-Term Delivery Strategy (LTDS) and the WRMP ambition for 2050 by efficiently maintaining the core estate infrastructure to enable effective operations and service delivery.

We have separately assessed and optimised each of the four areas of investment: Connect 2050; SPOF; Network Calming and Flood Alleviation. In each case we have selected the best value option, which has generally also been the least cost option. In most areas, it is shown to better to invest less and focus on the highest risk areas first, and then invest more in later AMPs when our understanding has improved. We have found that all of our preferred options are cost beneficial, particularly the network calming programme which shows a very strong cost benefit. We have considered options to increase the investment levels, but, although these are also cost beneficial, the uncertainties and level of benefits are not shown to be as attractive for customers.

Justification of the Preferred Option

Since AMP6 we have been identifying the resilience risks on our network and planning and undertaking base investments to strengthen our ability to supply to customers. We have improved our understanding of the effects of climate change and have started to fully adopt Ofwat's Operational Resilience Framework and incorporate the principles and methods into our asset and corporate planning processes. We have already improved our asset health reporting, data capture and analysis, and we intend to make further significant improvements in this area in the future to improve how we identify and prioritise our future investments for resilience.

In AMP6 we started a specific programme to address the high and medium frequency events as part of our base investments. This programme continued through AMP7 and will continue through AMP8. Our resilience enhancement investments, for AMP8, will focus on protecting the areas of our network that are prone to increasing climate change and emerging third-party impacts on our ability to supply water. This investment programme aligns and integrates with our network, WRMP and Long-Term Delivery strategies.

We have consistently found that the provision of safe, secure, supply of water is a high priority for customers. When considering resilience in this context, customers' generally focus on reducing bursts and leakage. Bursts can have a significant impact on customer satisfaction as they can lead to disruption, traffic congestion and pollution. Reducing leakage is consistently mentioned in any engagement that we do, and always features in the upper quartile of priorities. As such, there is strong support for investing to address resilience issues, particularly by proactively reducing the impacts of bursts on customers.

We have identified the enhancement SPOFs and analysed a number of programme options. We have selected the minimum programme of work within this AMP8 as it addresses the highest and most immediate risks and offers the best cost benefit. This programme of work strengthens the weakest points of our network to provide added resilience against the impact of climate change and emerging third-party impacts on our ability to supply. This work will contribute to the improvement of the resilience of our network, but the overall resilience will require other activities as defined in our base SPOF programme, WRMP and on-going investment to achieve the final desired performance.

Conservative estimates of the benefits have been made and the proposed programme is clearly cost beneficial in terms of the reduction in extreme supply interruption events. We have used conservative metrics in our analysis and believe that there are other un-quantified benefits to be realised. We will review the benefits as the project progresses and when we have better estimates of the different benefit metrics.

Our sensitivity analysis shows that the programme will be cost beneficial if the frequency of the extreme events is less than 1 in 800 years whilst ignoring any other benefits. When this is considered with our conservative assumptions, this assessment has determined the project is worthwhile and will be beneficial to customers, the environment and society.

We could do more, but the cost benefits reduce and the uncertainty of gaining value for customers diminishes. We appreciate that it is difficult to forecast climate change any other risks and so our assessment has been conservative. We believe that the best way to mitigate against these risks is with an on-going long-term programme of work that focuses on the more immediate and highest risk areas and learns and adapts over time. We believe that this offers best values for customers by focusing on best value investments, being prudent on our activities and ensuring affordability to customers, whilst planning for the future.

Delivery Considerations

Related Projects

For sustainability reductions (WINEP), any new SPOFs created will be funded under the Supply 2050 programme.

Under the Capital Maintenance Programme, we have specific considerations. For Non-Infra Capital Maintenance, we will not create new SPOFs as a result of these works. Similarly, for Infra Capital Maintenance, we will avoid creating new SPOFs.

When it comes to low pressures, the optioneering process will carefully assess the interdependency between SPOF schemes and low pressure. This assessment recognises both the potential risks and benefits associated with this relationship.

Lessons Learnt

The major lesson learned from addressing SPOFs in previous AMPs is the importance of conducting a thorough review of the valves recommended to be operated on the trunk main mitigation report and previous incidents. This review ensures that the contingencies outlined in the trunk main reports can be effectively implemented. By carefully examining the valves, their functionality and past incidents, potential risks and challenges can be identified and addressed proactively.

In addition to valve reviews, it is crucial to have a comprehensive understanding of the time required to repair a burst. This understanding involves considering several factors that influence the repair process, including the location of the burst and the type of material involved. By assessing these factors and their impact on repair timelines, accurate contingency plans and realistic expectations can be developed. This knowledge empowers the organisation to respond swiftly and efficiently to burst incidents, minimising disruptions to the water supply and ensuring customer satisfaction.

Delivery Risk Management

It is of paramount importance that we do not introduce new Single Points of Failures (SPOFs) in our upcoming projects. To achieve this, we will be adhering strictly to our established Risk Management approach. This procedure not only ensures that we are in line with the statutory requirements set out by UK law but also meets the standards prescribed by Ofwat and aligns with industry best practices. In the context of delivery, we have highlighted potential risks associated with the programme and our strategies for mitigation in the table below.

Risks	Mitigations

Create new SPOFs in new projects	Update design standard and resilience assessment. Potential programmes: • Abstraction Reduction (WINEP) schemes • Restricted main (removal of dead legs) etc. • Mains Renewal rationalisation • New Reservoirs
Build stranded assets	The programme can flex and phase to accommodate developments that will not happen
Create water quality hazards	• Larson-Skold effect • Turnover in pipes
Reliability from neighbouring Water Companies	Early Engagement with Thames and Anglian to understand how much water can be supplied and potential new connections
The inability to locate buried assets promptly during operational incidents can become a significant issue for a SPOF. For instance, in the case of the Baldock 16"/8" Burst incident in 2017, there were two valves on this cross-connection that could have potentially been closed to facilitate the repair and reopening of the mains. However, these valves could not be found, resulting in 8,000 properties being without water.	Trunk main Maintenance Programme

Further detail regarding how we have ensured the deliverability of our full investment portfolio is provided within AFW 32 Deliverability of our Plans.

Monitoring and Reporting of Benefits

The monitoring of the benefits of the SPOF business case will encompass evaluating interruption to supply performance, analysing risks reported on ARM, reviewing network infrastructure in monthly meetings (NIMMs), and conducting CLA analysis every two years.

Carbon Assessment

As mentioned on the section above, this business case was screened with relevant Business case leads to ascertain where there was potential for material impact on Carbon. Below in Table 7 can be seen a summary of the carbon assessment.

Option 1, aimed at eliminating all Single Points of Failure (SPOFs), is associated with the highest level of embodied carbon. This is due to the need for redundant systems and additional infrastructure, resulting in increased carbon emissions during manufacturing, transportation and installation.

Embodied Carbon (kgCO2e)

	Option_1	Option_2	Option_3	Option_4	Option_5	Option_6
Total	2,666,340	2,115,273	1,410,182	705,091	-	-
Total Civil Works	2,653,270	2,115,371	1,410,248	705,124	-	-
Total M&E	13,071	- 99	- 66	- 33	-	-
Total ICA	-	-	-	-	-	-

Table 7: Embodied Carbon assessment

Supporting Information

Files available on request.

- SPOF list
- Risk and Value Manual
- Carbon assessment
- Economical assessment
- Affinity Water network strategy
- How customers understand resilience
- Performance commitments
- What our customers and stakeholders want
- Delta Opex
- Asset Risk Manager Procedure
- PR24 DPC
- Asset Resilience Tool-SPOFs

Appendix 1: Asset Resilience Tool

Introduction

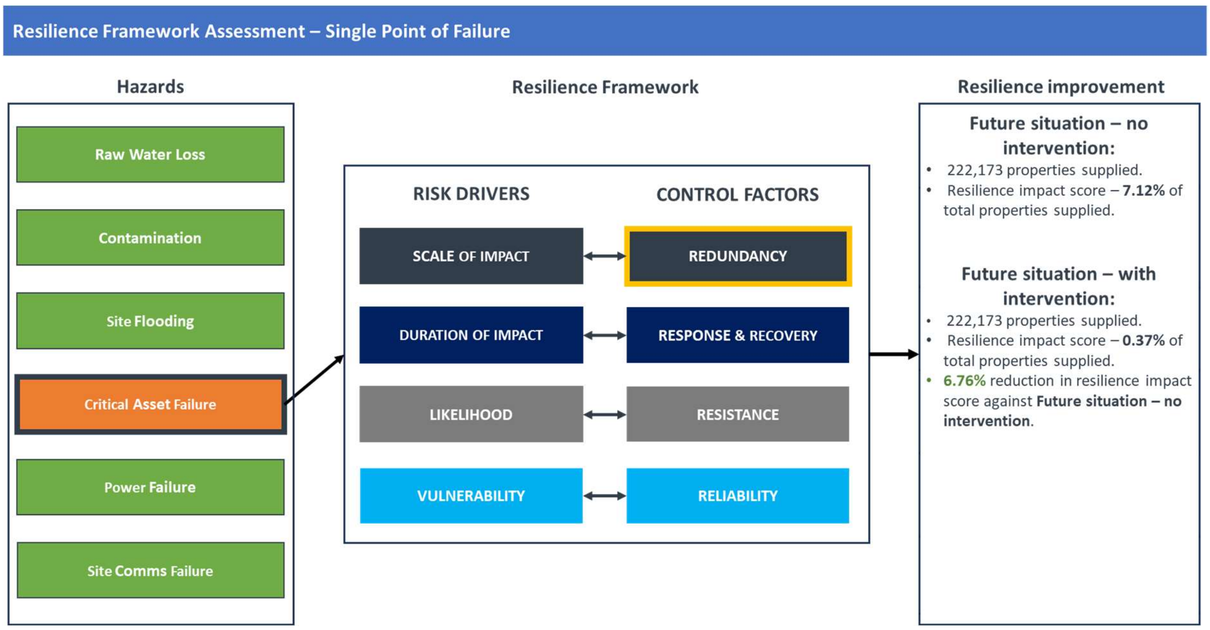
We are committed to providing a resilient water supply that meets the needs of our customers now and in the future. Following on from our PR19 Resilience Action Plan, we developed our Integrated Resilience Framework and Asset Resilience Tool to help us identify, understand and actively manage the risks to resilience that we face, ensuring all risks to resilience are approached consistently, with an understanding of how the risk impacts outcomes and is applied through investment decision making, long-term adaptive planning to assess the best options to manage them.

Our Asset Resilience Tool uses an asset by asset as well as a system-based approach in line with the 4R's methodology and assesses the risks from a broad range of hazards. This tool has been used to demonstrate the resilience benefit and provide additional justification to the AMP8 Single Points of Failure schemes.

This project aims to resolve Single Points of Failures to provide adequate level of resilience to the various shocks and stresses that Affinity Water's assets face, and ensure continuity of service to customers. SPOF vulnerabilities can arise when critical components, such as trunk mains or key infrastructure, are compromised, resulting in service interruptions and inconvenience for customers. The consequences can be particularly severe when a SPOF impacts many properties, potentially leaving thousands without access to clean water.

The schemes selected prioritise infrastructure and non-infrastructure assets to achieve an optimal balance between risk, cost, and performance to respond to the increase of frequency of drought events and improving the Redundancy of the system.

Summary of Findings



How the Tool Was Used

Once all affected assets have been identified, we used our resilience tool to calculate the Asset and Zonal resilience score against two scenarios:

- Future AMP 8 scenario if we do not do the proposed investment
- Future AMP 8 scenario if we do the proposed investment

This approach allows us to quantify the impact on resilience and understand the benefits of the proposed scheme by comparing what would happen if we did or did not do the proposed investment.

This was then modelled against the different hazards that are part of the tool. During the assessment we identified that the **Critical Asset Failure** Hazard was the most impactful for this analysis and our area of focus for the assessment due to the nature of the scheme.

Once the individual Asset Resilience was calculated, we determined the affected routes of water and proceeded to calculate the System resilience impact against the 2 scenarios. The outcome will provide a quantification in resilience impact score as a percentage on both scenarios and a percentage change against the different scenarios.

For more detail on how the scores are calculated see the Appendix AFW07 – Update on our Resilience Plan.

Assumptions Made

- Assessment done against two main scenarios.
- Critical Asset Failure Hazard was the most impactful for this analysis and our area of focus for the assessment due to the nature of the scheme.
- Routes of water have been simplified to focus on the affected assets.
- Some deterioration of the assets was included to account for the time when the schemes are required.
- New proposed assets have been assumed to be in very good condition.
- Properties impacted were identified in the respective Trunk Mains mitigation reports. If any of these SPOFs mains fail, the customers evaluated in the assessment will not have any alternative supply options.
- Proposed works will improve the current Redundancy by eliminating the SPOFs.

Trunk Mains Affected

The following trunk mains have been included under this assessment:

- TP37 and TP 38, R018, R025, R020A, R021 and R023, TP29, HH18, IV13, TMW H06 and TMW H12, TP42 and TP41, TPE 09, TMC J29, E043, TP39 and TP40, TP45 and TP60, ST18 and ST 69, B003 and B005, TME C04, TME C07and TME C08, TP19, TP20 and TP21, E024, TP22, AM77 and AM79

Data Used

- GIS information such as size, material, age, burst history, number of crossings and connections to other Trunk Mains
- Burst rate from Pioneer
- Trunk Main mitigation and contingency reports
- Spare parts availability
- Trunk Main monitoring systems
- Maintenance strategy

Results

Using the Asset Resilience Tool for the **future situation with no investment**, the tool indicates a combined Resilience Impact score of **7.12%** from the 222,173 properties identified. This result is overall due to the redundancy of the assets associated with the lack of rezoning when the assets fail. This Resilience Impact score is a combination of the results of all proposed schemes with some of the major assets scoring above **10%** impact score.

Using our resilience tool, the average Resilience Impact score for **Critical Asset Failure** hazard on our trunk main assets is **0.76%**. The combined score of sites identified under this project scores **9.4** times higher than the average score.

When we introduce the **proposed investments** to the tool, the Resilience Impact score will be **0.37%** of the 222,173 properties identified which is a **6.76%** reduction when compared to the current situation if we do not do the proposed investment. Improvements in asset redundancy, resulting from specific interventions, will enhance network resilience. The scope of these interventions provides the best value proposition, striking an optimal balance between risk, mitigation and performance.

Affinity Water

Emergency Planning (SEMD) Scheme

July 2023

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Summary

The Drinking Water Inspectorate (DWI) has issued a Section 28(4 Notice which includes the requirement to improve treatment at the site and if the company fail to comply it may result in enforcement proceedings under Section 18 of the Water Industry Act 1991. The new treatment is to address the risk of supplying water that could constitute a potential danger to human health from the presence of Cryptosporidium oocysts in the River Thames water. Ingestion of these oocysts by humans can lead to severe diarrhoea and vomiting, which can be life-threatening for individuals with a weakened immune system.

The notice describes that Affinity is to design, construct, commission additional treatment options, or modifications to existing treatment and include:

1. A validated UV irradiation system for the inactivation of Cryptosporidium oocysts (delivery AMP7).
2. Optimisation of the clarification process.
3. Additional rapid gravity filters to treat full output of Iver treatment works.
4. Covers for the GAC filters.
5. The upgrade of the wastewater treatment plant to improve water recirculating to the head of the works.

Item 1 is being delivered in AMP7, and this business case describes the optioneering process that has been completed to ensure items 2, 3, 4 and 5 are addressed with the optimum investment considering the timescale and future requirements for the site. The selected option represents the best value both in terms of the lowest initial capital expenditure and in line with our long-term delivery strategy.

Project Details

AMP8 Spend	2025-26	2026-27	2027-28	2028-29	2029-30	Total
Capex (£m)	18.19	18.19	9.10	0.00	0.00	**45.48**
Opex (£m)	0.00	0.00	0.20	0.40	0.39	**0.99**
Totex (£m)	18.19	18.19	9.30	0.40	0.39	**46.47**
Drivers						
100%	Addressing raw water quality deterioration (grey solutions)					
Benefits						
Loss of Production Capacity (Ml/d) Compliance Risk Index (score)						
Economic Analysis						
NPV Costs (£m) (2025-55)	**47.5**	NPV Benefits (£m) (2025-55)			**98.6**	
NPV (£m) (2025-55)	**51.1**	Benefit / Cost Ratio			**2.1**	
Six Capitals						

Natural	Social	Financial	Manufact.	Human	Intellectual
	★ ★ ★	★	★ ★		

Project Description

The Drinking Water Inspectorate (DWI) has issued a Section 28(4) Notice which includes the requirement to improve treatment at the site and if the company fails to comply it may result in enforcement proceedings under Section 18 of the Water Industry Act 1991.

The notice sets out a number of steps that are required to take to mitigate a significant risk of supplying water that could constitute a potential danger to human health or could be unwholesome. The new treatment is to address the risk from the presence of Cryptosporidium oocysts in the River Thames water. Ingestion of these oocysts by humans can lead to severe diarrhoea and vomiting, which can be life-threatening for individuals with a weakened immune system.

The DWI have detailed a number of steps that Affinity Water needs to take at Iver to ensure that this risk is mitigated now and in the future. The notice describes that Affinity is to design, construct, commission additional treatment options, or modifications to existing treatment and include:

1. A validated UV irradiation system for the inactivation of Cryptosporidium oocysts (delivery AMP7).
2. Optimisation of the clarification process.
3. Additional rapid gravity filters to treat full output of Iver treatment works.
4. Covers for the GAC filters.
5. The upgrade of the wastewater treatment plant to improve water recirculating to the head of the works.

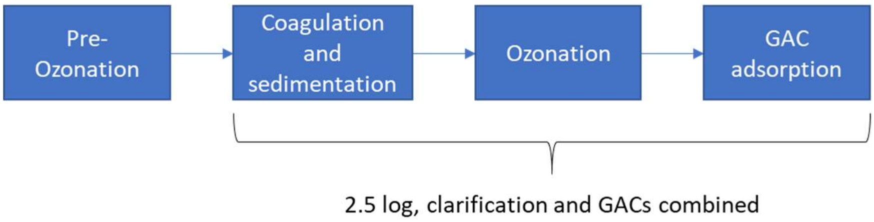
The design of these works (exc. UV) will need to be complete by November 2024 and, the construction and commissioning to be complete December 2027.

Project Development

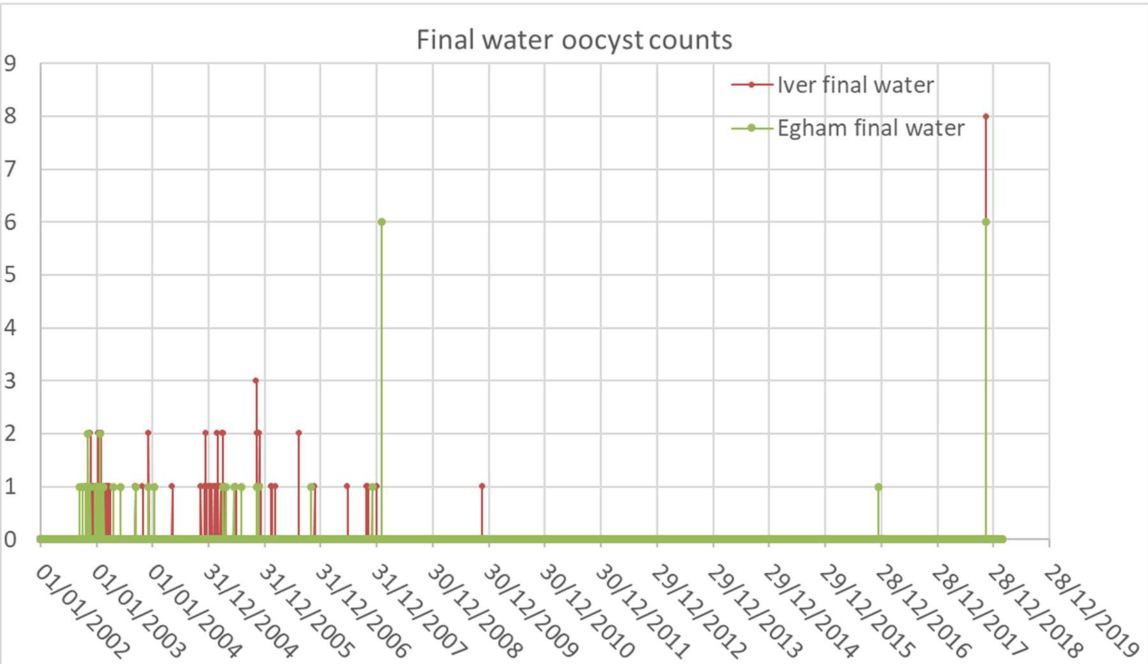
Baseline Assessment

The treatment process chain at Iver WTW comprises direct river abstraction (with partial blending from TWUL reservoirs), pre-ozone dosing, coagulation and sedimentation, inter-ozone dosing, GAC adsorption, UV irradiation and disinfection with chlorine.

In the 1990s, the rapid gravity filters (RGFs) that were in operation at Iver WTW were repurposed as granular activated carbon (GAC) contactors to address pesticides and taste and odour in the raw water, along with use of ozone. The dedicated filtration stage was not replaced. This means that the particle and Cryptosporidium oocyst removal capability at Iver is limited to 2.5-log (99.7%).



The graph below shows Cryptosporidium oocyst detection in the final water at Iver and Egham since 2002. Since between 2007 and 2018 there was only one incident on each works of final water oocyst detection and neither event was reportable. It is possible that with changing weather patterns due to climate change, long dry periods in the summer followed by sudden heavy rainfall and ‘first flush’ events, the incidents of high Cryptosporidium concentration in the River Thames could increase.



Whilst we describe our treatment processes as robust we also know they are not absolute, and that a level of risk remains should the concentration of Cryptosporidium oocysts in the river water peak at very high concentrations.

Problem Statement and Stated Need / Driver

The Drinking Water Inspectorate (DWI) has issued a Section 28(4) Notice which includes the requirement to improve treatment at the site and if the company fail to comply it may result in enforcement proceedings under Section 18 of the Water Industry Act 1991. This was in response to an event 'Cryptosporidium detection at Iver and Egham Water Treatment Works November 2018 (DWI Ref: 2018/6901)' outlined below.

Samples taken between 10th and 11th November 2018 from Iver WTW and Egham WTW detected Cryptosporidium oocysts in the final water from each site. The risk posed by Cryptosporidium oocysts is that their ingestion by humans can lead to acute cryptosporidiosis causing severe diarrhoea and vomiting, which can be life-threatening for individuals with a weakened immune system.

There was a risk that we would need to impose a Boil Water Notice (BWN) to 1.2m Affinity Water customers (including Heathrow Airport) and 0.1m South East Water customers to protect them from these health impacts. Subsequent samples were fast tracked through the laboratory and we were able to confirm that this was a short-lived event and no BWN was required.

We engaged immediately with multiple agencies across our company area to keep them updated on events; Public Health England Health Protection Team, Local Authority, Environmental Health Teams, CCWater, Water Security and Resilience team at Defra and Drinking Water Inspectorate (DWI). We also engaged with the Environment Agency (EA), Thames Water Utilities (TWUL) and South East Water (SEW).

TWUL confirmed that there had been no operational issues with any of their sewage treatment works that discharge into the River Thames, or its tributaries, upstream of our abstraction points. This is supported by the fact that the species of oocysts identified was Cryptosporidium Parvum, which is not specific to humans, so the source could have been human or animal. The EA confirmed that there was no pollution report linked to the event in the relevant parts of the Lower Thames catchment leading up to the Cryptosporidium detection.

To date we have found no obvious cause of the high concentrations of Cryptosporidium oocysts in the raw water, but investigations have modelled a deterioration in river water quality around the Maidenhead area, and a point source pollution is suspected. It is unlikely that the source of this particular pollution event will be identified now but there is still a need to identify catchment risks and engage with those stakeholders.

An initial investigation report was submitted to DWI and follow up report (20 day) with greater detail was submitted 7 December 2018. We received an event assessment letter from DWI on 14 March 2019 and we received a Notice from DWI on 18 April 2019.

Whilst we describe our treatment processes as robust we also know they are not absolute, and that a level of risk remains should we encounter further gross pollution events. As a result, we have considered several options for managing and mitigating the remaining risk, investigating the feasibility, timescale, level of risk, and approximate costs associated with each.

Risks, Issues and Requirements

Our statutory obligations in relation to water quality are contained in section 68 of the Water Industry Act 1991 and the Water Supply (Water Quality) Regulations 2016 ("Water Quality Regs"). Section 68(1) of the Water Industry Act 1991 provides that a water undertaker has a duty in relation to water supplied for domestic or food production purposes:

a) to ensure that any water so supplied is wholesome at the time of supply; and,
b) so far as reasonably practicable, to ensure, in relation to each source or combination of sources from which water is supplied, that there is, in general, no deterioration in the quality of water which is supplied from time to time from that source or combination of sources.

Water is "wholesome" if it meets the standards prescribed in Regulation 4 of the Water Quality Regs, including the following requirements, among others:

a) that the water does not contain
   i. any micro-organism (other than a parameter listed in Schedule 1) or parasite, or
   ii. any substance (other than a parameter listed in Schedule 1), at a concentration or value which would constitute a potential danger to human health.

To provide adequate solids removal at Iver, under challenging raw water quality conditions, we currently reduce flow through the works and/or blend the poor-quality raw water with an alternative raw water source (Thames Water Reservoir Import) to reduce the likelihood of Cryptosporidium oocyst breakthrough. This ensures that we can maintain the wholesomeness of drinking water in the areas receiving water from Iver.

As we shift our abstraction away from the chalk groundwater sources in favour of maximising the use of surface water to protect the chalk stream environments, in line with the LTDS Core Pathway approach on Abstraction Reduction, we will experience changes in the supply-demand balance in these communities, and it will not be possible to continue to reduce flow *and* meet demand in the future. The Core

Pathway for WRMP requires the surface water treatment works to produce water reliably, at 227Ml/d for Iver and 140Ml/d for Egham.

We also need to consider the requirement in section 68(1)(b), which relates to deterioration in the quality of water supplied to customers. It provides two overarching principles in relation to this duty:

- that the company should not expose consumers to a greater risk of exposure to unwholesome water; and
- that the company must always plan to meet its water quality obligations (paragraph 4.3.3).

If we were to supply water from Iver treatment works at the full site flow capacity without enhancing the level of treatment provided we would be exposing our consumers to a greater risk of receiving water that is unwholesome and in doing so we would be knowingly risking not meeting our water quality obligations.

The DWI Guidance explains that the standard of no deterioration should be measured by reference to compliance with the standards of wholesomeness (paragraph 4.3.6) specifically:

The Inspectorate interprets the statutory requirement for 'no deterioration' by reference to compliance with the requirements of the Regulations, including standards. A marginal change in the concentration or level of a parameter may not be considered as deterioration if the water as supplied remains wholesome and is acceptable to consumers, provided that the company can demonstrate that it has considered and limited the deterioration as far as is reasonably practical to do so.

The provision of enhanced treatment at Iver treatment works is a mitigating measure that would ensure there is no increase in the risk of supplying water that does not meet the requirements of the Water Quality Regs in the future, when higher flows from these works are required. The works would do this by ensuring that we are meeting the industry standard best practice level of treatment for Cryptosporidium, under all flow and typical raw water quality conditions. Delivering this work will also demonstrate that we have "considered and limited the deterioration" due to increasing flows through the two treatment works as far as is reasonably practical.

Allocation of Costs

Due to the improvement in the site and its subsequent future performance the costs associated with the DWI notice letter would be deemed as enhancement. As the graph 'final water oocyst counts' in the baseline assessment section shows, the event leading to the DWI notice was at a higher level than previously experienced, and as such requires a step change in our treatment process and ability to cope with such events.

An exercise was carried out to ascertain whether there would be any overlap with Base costs in AMP8. The majority of the scope required by the solution detailed in this business case is related to building additional treatment in the form of a new RGF filtration stage, and therefore will not have any overlap with existing base capital maintenance activity. Other parts of the scope relate to improvement of the Actiflo clarification process, and increasing capacity of the wastewater plant on site, the method by which this is achieved is to be verified using pilot trials.

Pioneer is used to model predicted costs based on asset deterioration models, and this was analysed for the potential AMP8 intervention costs in these two areas. There are no significant planned or reactive costs forecast in the model.

An assessment of existing issues was also carried out to determine if they would have required investment in AMP8, and if the scope of this project would address them. The conclusion is that a major overhaul of the wastewater system is not necessary from a process standpoint, but upgrade and modifications are necessary to deal with the increased capacity, as well as ensuring the project can be delivered within the capacity of the available power supply. Therefore, there are no base costs being addressed as part of this enhancement funding in the wastewater part of the scope. None of the scope detailed in the preferred solution has been previously funded in earlier AMPs.

DPC

Direct Procurement for Customers (DPC) is not applicable to this investment as it falls below the cost threshold of £200m.

Research, Pilots, and Technology Development

Initial optioneering focussed on tried and tested technologies for the water treatment options, but at a later stage the more recent development of ceramic membrane technology was included for appraisal. A site visit to a ceramic membrane in operation at South West Water's Mayflower WTW was undertaken by a team from Affinity water to understand the potential suitability for use at Iver or Egham.

Relating to the need to increase waste treatment capacity in line with the preferred solution, the actual method is yet to be finalised. Volute dewatering has been proposed as an alternative to expanding the existing process, but due to unknowns with the performance with the particular water quality at Iver, piloting will be an essential step before any implementation of the technology.

Customer Engagement

Detail of Customer Engagement work

We have undertaken extensive engagement with our customers to build a detailed understanding of their priorities and reflected these in this business case. For more detail on our customer engagement see AFW04 What Customers and Stakeholders Want.

We carried out some customer engagement[1,2,3,4] as part of the Strategic Resource Options programme of work, looking at how customers preferred to be communicated with. This gave us the opportunity to gain some insights into their thoughts and preferences about several of the long-term plans related to water resourcing, including source types.

An evidence review was carried out of 50 documents and stakeholder interviews with each of the water companies, with documents gathered directly from the 6 water companies involved in WRSE, and the evidence was then synthesised to identify consistent findings which were triangulated to assess their strength. During the qualitative phase we tested these findings with 96 household customers across the 6 companies, including Gen Z and vulnerable customer. During the quantitative phase we held 15-minute online surveys with 1,762 household and 198 non-household customers for robust segmentation and validation of findings.

This research reinforced our understanding that water is a low salience topic with our customers, in that they have a low level of awareness and understanding of issues relating to it. This in part is driven by general satisfaction with the customer experience of water in terms of taste, smell and hardness.

We followed this up with some deep dive sessions in July 2022 to specifically test on our own long-term plans with a wide cross section of our customer base[5]. 82 customers and 10 business representatives participated in this research. Customers were divided into 'household', 'vulnerable' and 'future' groups to reflect a range of views, whilst local business representatives provided views on behalf of their place of work ('Non-household').

The Non-household individuals were recruited from businesses which are heavy water users. Customer groups covered a range of ages, socio-economic backgrounds and areas within Affinity Water's region in order to enable a diverse range of views. Given the long-term focus of the research, future customers were also included to gauge an understanding of priorities from individuals who are likely to become Affinity Water customers in the future.

[1] WRSE Customer Preferences_Part A Evidence Review_Final Report_eftec ICS_February 2021.pdf
[2] Water Club - Changes of Source - June 2022.pdf
[3] Affinity Water Customer Valuation Research Summary Report May 2023.pdf
[4] Affinity Water Customer Priorities for Long-term Ambitions
[5] 'Customer Priorities for long-term ambitions to support PR24 and long-term delivery strategies,' September 2022

Ten online focus groups were held (household and future customers) and fifteen one-to-one interviews conducted (vulnerable and non-household customers). Focus groups were conducted via online video, using the specialist VisionsLive platform, each session lasting 90 minutes. Voting exercises and activities were used throughout the focus groups, to aid engagement, capture strength of feeling, and focus the discussion on the core research questions.

These were qualitative sessions and the outcomes gave us some insight into customer views of the relative importance to them of, among other considerations:

- Reducing amount of chemicals used in water treatment,
- Reducing carbon emissions associated with treating water for customers,
- Hardness level of their water supply, and
- Keeping customer bills as low as possible.

Finally, we held some quantitative research sessions between February and March of 2023 with a second set of workshops looking at Customer views on priorities covering customer preferences for changing service levels. Customers were generally observed to be more sensitive to avoiding deteriorated service levels compared to the preference for improvements. In general, there was a limited preference for changes in service levels for hard water and hosepipes bans.

911 household customers completed the survey between February and March 2023 800 respondents completed an online survey and 111 completed an in-person interview, qualifying as "digitally disengaged." 42% of the household respondents (383 people) were classified as being in vulnerable circumstances. Around 13% of respondents who took part in the study (117 people) were registered with the Priority Services Register. Of these 117 respondents, 31% were medically dependent on water, 56% suffered from physical issues, and 9% need information in alternative formats.

There was a good distribution among the respondents of all targeted characteristics. Females were slightly over-represented (57% of respondents) and were within +/- 7 percentage of sample quotas. Socio-economic group (SEG) profile were within +/- 3 percentage points of sample quota. All age cohorts were within +/- 4 percentage points of sample quotas.

150 non-household (NHH) respondents completed the survey online. These comprised a good mix of NHHs achieved when measured by both number of sites and by number of employees. Around a third of organisations had only 1 site (34%), 12% of respondents were a sole trader and 15% of respondents had between 100-150 employees. Also, the sample distribution by economic sector has the expected profile with 1% as Primary, 28% as Secondary and 71% as Tertiary.

Evidence of Customer Preferences

We have developed all of this research and analysis into a document called 'What our Customers & Stakeholders Want[6]' which presents the findings from the various customer engagement activities. The key takeaway point from the research is that customers have a high level of inherent trust in us as a water provider, and generally are happy for us to make decisions about technology selection and water quality risk management without consultation with them – we are the experts, and they trust us to make those decisions.

Another outcome of the research was a strong steer that customers expect us to meet our regulatory duties at all times, with respect to the Water Supply (Water Quality) Regulations. Any strategic decisions we make with respect to cost or carbon emission reduction must not have any detrimental impact on water quality performance.

The outcomes from the deep-dive qualitative sessions with our own customers indicated that they have wide ranging responses to the questions of whether we should be reducing chemical use in water treatment and whether we should be reducing operational carbon emissions, which could be influenced by many factors including the respondents' own socio-economic group, with no overall preference or point-of-view expressed[7]. There was a clear steer from customers, from these qualitative sessions, that their main priority over any of the other considerations was to keep bills as low as practicable.

The SRO customer communication preferences work indicated that there are some acceptance barriers in place for customers around some of our water resourcing ideas, particularly with respect to direct or indirect wastewater effluent reuse schemes. They indicated that they would need reassurance if this type of approach were taken that water would be safe to drink.

The qualitative research sessions indicated that customers were generally observed to be more sensitive to avoiding deteriorated service levels compared to the preference for improvements. Household customer values for improved service levels for areas including tap water aesthetics was relatively modest – but nevertheless improvement in these areas was viewed as beneficial. In general, there was a limited preference for changes in service levels for hard water and hosepipes bans. Respondents felt that Affinity Water's services are good value for money and were generally satisfied with the services they receive.

Customer protection

Customers will be protected through a Price Control Deliverable for this project, which will be aligned with the requirements set out by the DWI in the Section 28(4) Notice. The PCD will cover all the benefits that we propose to deliver under the requested funding.

[6] What our Customers and Stakeholders Want V5 final.pdf

[7] Line of sight V2.docx

There will be no third-party funding or delivery arrangements as part of this work.

Partnering

Collaboration and Partnering

Engagement with Stakeholders and Partners

Stantec, one of Affinity Water's Professional Services Partners was engaged to carry out a strategic assessment of the options for the development of Iver Water Treatment Works. The Stantec project team worked closely with Affinity Water stakeholders to understand the current site treatment processes and condition, the need relating to the DWI notice, and checked in at various stages through the assessment and optioneering process.

During optioneering, engagement commenced with internal stakeholders, and with regulators as set out in the DWI notice, as well as equipment suppliers. As part of the UV project we have engaged the local electricity operator and they have stated there will not be sufficient power available at the National Grid level prior to 2027 and with its proximity to the M4 corridor this could be much later, 2035. Therefore, any solution will need to be within the existing peak power operating ranges. To address this we are working with our partners to identify energy saving opportunities across the site asset base, and incorporating a proportion of renewable energy in the form of PV cells on the GAC filters with battery storage.

Stantec engaged the services of Aqua Consultants, commercial engineering consultants with particular experience of the water industry, to produce cost and carbon estimates. Aqua hold a mature and extensive database of estimating material. Cost estimates have been prepared using a combination of cost models and unit costs based on experience within the Water Industry, through AMP7 and AMP6, PR19 and PR24 as well as budget estimates from the market.

<u>Drinking Water Inspectorate (DWI)</u>

The DWI under the statutory notice require us to report at different stages to ensure that we are on track with delivering the intended outputs as laid out.

In December 2024 we will submit our final option for Iver Water Treatment Works for the listed deliverables as per the section 28 notice. At this stage we will need to commence detailed design and build of the solution to meet 2027 completion date.

<u>Environment Agency</u>

As part of the scope is to determine option for the run to waste facilities of the site. This is detailed in the relevant business case and not discussed further here.

Co-design and Co-delivery

Currently, we are commencing a strategy whereby the optioneering for the outline design is being carried out by one of our partners Stantec. At the same time to ensure constructability and appropriate construction budgeting is taking place we will engage with our larger construction partner Galliford Try in early contractor involvement (ECI) to assure that what is produced is both deliverable and affordable.

Strategy Development

All of our enhancement cases have been developed as part of our integrated investment portfolio that takes the first steps of our Long Term Delivery Strategy and achieving our ambitions as laid out in AFW03 Strategic Direction Statement.

Long-term Delivery Strategy Alignment

In our Strategic Direction Statement[8] we commit to "Deliver what our customers need, ensuring affordability for all" which encompasses "Exceed[ing] customers' expectations for drinking water." Our customer consultation work has confirmed that customers hold inherent trust in us to make the appropriate interventions to safeguard their water quality.

There is an additional commitment to "Be prepared for change and resilient to shocks and stresses" within which we commit to "Ensure a resilient supply of water for Affinity Water customers." We are delivering on this commit in this case by providing treatment where no blending or other management of the risk is possible without detrimental effect on the resilience of our supply.

Our long-term delivery strategy related to water treatment includes an investment line covering "Addressing raw water deterioration." We have delivered multiple workstreams to address the risk from Cryptosporidium at the source in our catchments, with further information on this in the optioneering section.

An optioneering study has taken place with Stantec, one of our Professional Services Partners to ensure the following was considered;

'In addition to the satisfying the DWI requirements with respect to the Cryptosporidium risk the key project drivers include the following requirements to be considered by the Consultant:

- Maximise the utilisation of existing infrastructure.
- Reduce net operating expenditure.
- Reduce net operational carbon footprint.
- Minimise embodied carbon footprint.
- Ensure relevant installations and construction works are within the existing site boundary.'

These align with our long-term commitment and the output of the outline design will then be used to construct the necessary environmental strategy for the construction phase.

The investments proposed within this business case are aligned with the Core Adaptive Pathway for Iver WTW in our LTDS and will not adversely impact any of the potential

[8] AW0031_Strategic-direction-statement.pdf

Alternate Pathways identified. The investments will still be required under all common reference future scenarios.

Treatment Strategy

Currently, our Treatment Strategy requires provision of treatment only when necessary due to raw water quality and when it is the best value holistic solution to provide treatment rather than any other solution.

We are exploring options around selection of the final options for the DWI deliverables and the criteria above. These key criteria will enable the successful delivery of the project within the tight timescales. These align with the current investment strategies.

The WRMP strategy clearly requires a baseload performance at Iver and Egham post-AMP8 in order to maintain the supply-demand balance in the Central region. It is essential that the two treatment works can provide 227Ml/d and 140Ml/d respectively for a prolonged duration to enable the water supply strategy, and this investment is critical to enabling this.

Adaptive Strategy

The solution will need to be adaptive due to the peak power issues at Iver as described above. This may mean that other treatment process will need to be modified as a result to maintain the current demand. The solution will be challenged to ensure it is within the site power capacity.

A project steering group has been setup from WQ, Asset Strategy, Capital delivery and Operations to ensure ideas/issues/challenges are discussed from all perspectives to ensure robust challenge from all parties to satisfy our strategic goals for the project.

This project is no regrets because we require the water from the sources to meet our supply demand balance and, without the addition of treatment processes at Iver, we predict we will otherwise need to continue to reduce its output in AMP8 when river water quality deteriorates.

While the DWI notice gives a compliance date of 2027 for the installation of adequate filtration, the aim of this project was to take a longer view for the site, extending past AMP 8 into AMPs 9 and 10. There is an acknowledgement that it may not be feasible to carry out all of the changes required in a single AMP, so short term changes may be required which are then subject to change at a later date. Therefore, the solution derived from the project was to meet the short-term regulatory challenge, while still enabling Affinity Water to develop Iver into an industry leading "flagship" site, making use of new and developing technologies as they mature in the market. The results of the optioneering have been appraised to ensure the preferred option fits with the medium term outlook, and that investments will not be made obsolete by site enhancements in the near future. Furthermore the customer will be protected with Price Control Deliverables (PCD's) in line with the DWI notice commitments.

Optioneering

We have consistently proposed best value solutions using rigorous optioneering. For more detail on our approach is provided within AFW08 Our Investment Development Process.

A comprehensive optioneering process was undertaken, following on from a full optioneering report that was submitted to the DWI in 2019 detailing the catchment, the current treatment process onsite and the options to deal with future pollution events with regard to Cryptosporidium.

An internal workshop was held to brainstorm all conceivable options that could mitigate a repeat of the incident in 2018, and the table below details these unconstrained options. This next step in this approach was to screen out any unfeasible options, whether due to lack of efficacy, space, or time to implement and take effect – thus any of the unconstrained options that would not fit, could not be built in time, or were not effective in meeting the requirements were discounted.

TREATMENT OPTION	SPACE	TIME	EFFICACY	INCLUDE
Do nothing	G	G	R	Y
Catchment management	G	A	A	Y
Alternative raw water source	G	A	R	N
Blending raw water	G	G	R	N
Optimisation of assets	G	A	A	Y
Bank side storage	R	R	A	N
UF membranes	G	A	G	Y
UV	G	A	G	Y
SSF (slow sand filters)	R	R	A	N
RGF (new rapid gravity filters)	G	A	A	Y
High rate clarifiers	G	A	A	Y
Blending final water	N/A	N/A	N/A	N

Of those selected to include in further optioneering, the catchment management option was one that was agreed to progress, but understood that in itself it could not provide a sufficient safeguard against future events.

We have delivered multiple workstreams to address the risk from Cryptosporidium at the source in our catchments, and updated our business as usual approach to catchment management following the incident in 2018 to incorporate review of satellite imagery to identify potential hotspots for risk. We have also rolled out online water quality monitoring on the River Thames upstream of our abstraction points to give early warning of potential pollution or high-risk events, allowing site operators to take appropriate mitigation action. It is not possible, however, to monitor presence of Cryptosporidium in real time so these monitors can only partially mitigate the risk by identify high-risk ‘scenarios’ on the river, e.g., high turbidity events.

Due to the large size of the River Thames catchment, the number of land-users and stakeholders who could impact the river quality and the impracticality of carrying out land use assessments over the whole area, all of this intervention is not sufficient to adequately reduce the risk of Cryptosporidium oocysts presence in the final water at either treatment works. The catchment management plan was agreed to occur alongside any treatment options.

A number of the additional site options were developed for Iver WTW, in close collaboration with colleagues from Production to ensure that they were practical, complete, operable and feasible. These options were:

1. UV irradiation post-GAC only;
2. Upgrade of conventional treatment processes on site, in line with industry best practice;
3. Upgrade of conventional treatment processes on site, with UV post-GACs; and
4. Upgrade of conventional treatment processes on site, with ultra-filtration membranes post-GACs.

The advantages, disadvantages and risks were discussed for the 4 options. However, the DWI determined what it wanted to be delivered within its section 28 notice. This resulted in the AMP7 project to install UV at Iver and Egham, with the understanding that the other options would be further developed for a subsequent phase.

Work to meet the additional AMP8 requirements in the notice continued with planning for further enhancements and began by engaging Stantec to develop the treatment options, following the steps shown in the timeline diagram below.

The brief given was to assess options to meet the DWI notices, but also included the need to take a longer term view, extending past AMP8 into AMP9 and 10 and ensuring any investments fit within the long term outlook for the site. This approach enables adaptive planning when considering future developments.

In Phase 1 Iver Strategic Options Assessment, through site visits and discussions with Affinity Water, various high-level options were identified to improve and optimise the site to meet DWI requirements. Matched-Paired Analysis and CAPEX estimates were evaluated and used to compare the various options. Alongside this a detailed assessment of the existing site capabilities was undertaken.

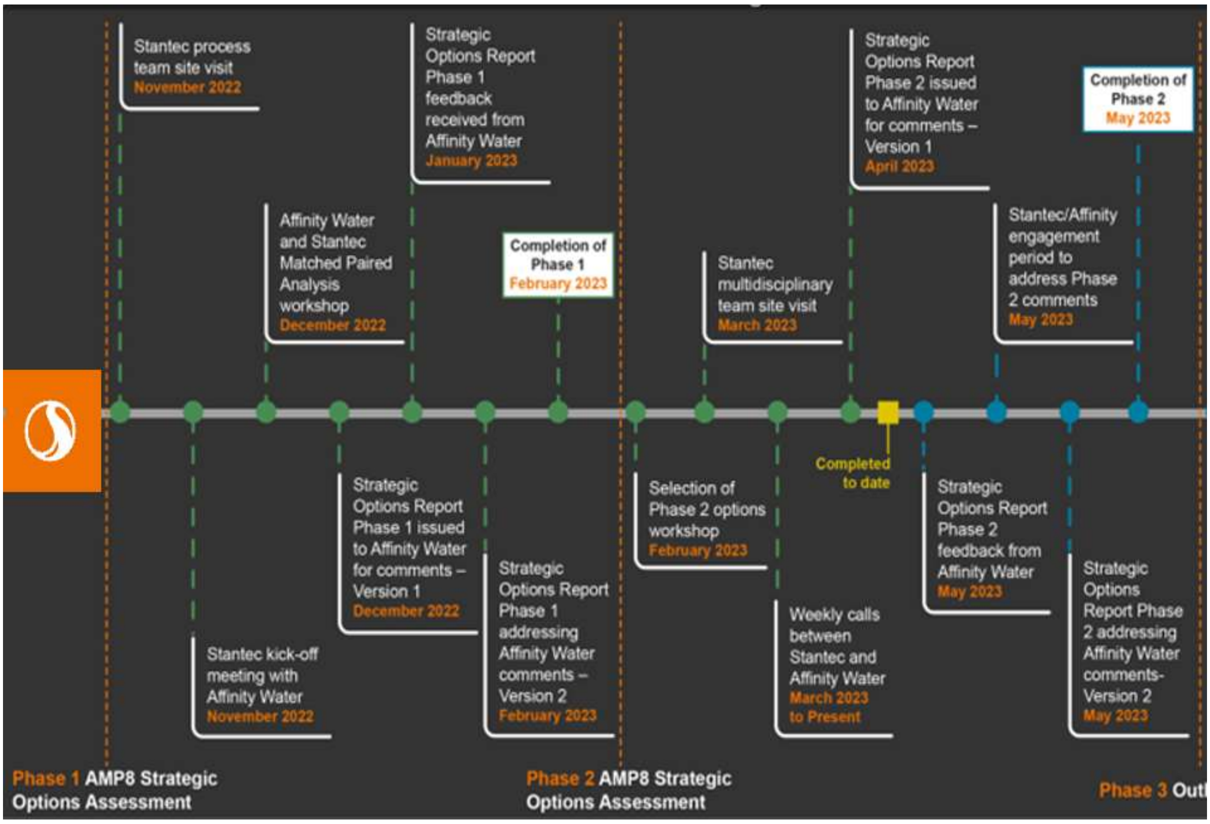
Following the submission of the Phase 1 Iver Strategic Options Assessment, a workshop, and continued communication between Stantec and Affinity Water, were used to narrow down four viable process options and a strategic plan for Iver WTW:

1. Existing asset upgrades + new RGFs
2. Install Actiflo plus RGFs

3. Submerged membrane plant
4. Ceramic membrane plant

Phase 2 then further investigated and developed these options. To learn more about the options in the specific context of Iver, water quality data provided by Affinity Water was analysed and used to set a design envelope which was then used to approach suppliers for solution designs and costs. Additionally, the envelope was used in the process modelling of each option using a modified version of the Affinity Water MIMIC_Iver_v2.0 model. This model was created in 2017 to analyse the existing site by MWH and was provided to Stantec by Affinity Water for use in this project. The original model was expanded and updated to reflect the current site conditions (e.g., the addition of more GACs) and a new version created to include each of the four treatment options proposed in this report. It was decided that the options would be designed around the maximum values of the sampling data analysed as opposed to the 95th percentile as is more common. This was done to account for future deterioration of the raw water abstracted from the Thames due to climate change and ensure that the design proposed has in built resilience to these changes

Continued development of these options included sub-options for different locations on the site. Stantec engaged in consultations with suppliers and stakeholders such as Nanostone, Veolia, SUEZ, and Evergreen Water Solutions and AQUA consultants. Environmental assessments, carbon calculations, and costings were carried out during this stage, and this work enabled qualitative and quantitative comparisons of the options.



Selected Options

For clarity, the option numbers will be referred to as they appear in the Strategic Options Report by Stantec, as per the table below:

Option 1:	Baseline/Existing/Do Nothing
Option 2:	**Existing Assets + RGF's [Location 1]**
Option 3:	*Existing Assets + RGF's [Location 2]*
Option 4:	*Actiflo + RGF's [Location 1]*
Option 5:	*Actiflo + RGF's [Location 2]*
Option 6:	**Actiflo + RGF's [Location 3]**
Option 7:	**Ceramic Membrane Plant**
Option 8:	**Submerged Membrane Plant**

Do Nothing, Option 1

This work is subject to a DWI section 28(4) Notice, therefore doing nothing is not considered a viable option.

In October 2020, a DWI notice was applied to the site requiring that changes be made to the process to optimise the performance of the entire treatment process, upgrade the waste facilities and add RGFs to the process.

Preferred, Best Value, Option 3

Existing assets + Rapid Gravity Filters [location 2, south-east of the site]

New assets shown in green, anti-clockwise from top left:

1. GAC covers incorporating solar panels on filters 13-24;
2. GAC covers incorporating solar panels on filters 1-12;
3. New RGF filters
4. New backwash tanks

[redacted]

The solution would maintain every process unit on site and add 18 RGFs to the site to improve solids removal. Clean backwash tanks and an intermediate pumping station would also be required for this option.

The existing filters need to be covered to prevent debris or contamination entering the filters as part of the DWI notice, and this would incorporate solar panels to assist with the increase in power supply required

The Wastewater treatments sludge holding tank that accepts backwash and sludge flows from the other units on site needs to expanded as the addition of RGFs will result in more flow to the tank. For this option, the run to waste on filter start up would have to be recycled to the head of the works.

Least Cost Option 2

Existing assets + Rapid Gravity Filters [location 1]

Same as option 3, but RGFs located in the free space on the north of the site.

[redacted]

Alternative Options 4, 5, and 6

Actiflo + Rapid Gravity Filters

For this option a new Actiflo unit will be constructed offline in the space available on site to replace the aging pulsator clarifiers. These pulsators would be decommissioned and a new Actiflo unit, a set of 18 RGFs and an intermediate pumping station along with connecting pipework would be added to the process. The other treatment stages such as inter-ozone and the GACs will be unchanged for this option.

The RGFs are required to meet the DWI notice applied to the site, and so are also required for this option. The construction of an Actiflo unit is likely to be a long-term investment, requiring RGFs for its entire lifespan.

The waste treatment process upgrades for this treatment option are similar to those in the existing treatment upgrade option. Measures such as increasing the size of the reception tank are equally valid for this option and would improve the treatment process.

Alternative Option 7

Ceramic Membranes

For this option, the entire existing clarification process would be replaced by a ceramic membrane plant, which would meet the DWI requirements applied to the site and satisfy a major project driver by acting as an absolute barrier to *Cryptosporidium*. In terms of process units on site, the ceramic membranes would replace both clarification processes on site and meet the requirements for RGFs, meaning none would have to be built downstream. An intermediate pumping station would still have to be constructed, but no other changes would be required to units such as the ozone plant or GACs.

Alternative Option 8

Submerged membranes

Submerged membranes offer a single stage treatment that can meet the DWI notice applied to Iver and provide an absolute Cryptosporidium barrier. The scheme would involve a large, submerged membrane plant being installed on site as well as an interstage pumping station to relift the flow. The membranes would replace the existing primary clarification processes (Actiflo and pulsator clarifiers), and remove the need for RGFs on site, simplifying the process.

Option Assessment Approach

Economic Assessment

All four of the options were analysed, including two further sub-options to assess alternative locations for the new plant. Each was assessed for capex, annual and 30 year opex, whole life costs, as well as NPV over 30 years.

Cost Estimation

Stantec engaged the services of Aqua Consultants, commercial engineering consultants with particular experience of the water industry, to produce cost and carbon estimates. Aqua hold a mature and extensive database of estimating material. Cost estimates have been prepared using a combination of cost models and unit costs based on experience within the Water Industry, through AMP7 and AMP6, PR19 and PR24 as well as budget estimates from the market.

The level of detail is developed to sub-process and key asset level, but is yet to progress to outline design stage, hence confidence level is medium.

Benefit Estimation

By meeting the DWI notice requirements by 2027, the preferred option will deliver the benefits of enhanced treatment, protecting customers from the health risk posed by cryptosporidium, and ensuring that the site output of 227Mld is attainable through all raw water quality conditions. The benefits to customers have been applied conservatively from 2030 and sensitivity analysis carried out as described below.

Efficiency

The DWI notice requires significant process changes and maximising the lifespan of existing assets whilst adding RGF units to improve treatment further is a very cost effective and environmentally sound option. The economic assessment section gives further detail on the comparison between options.

Assumptions Made

Assumptions made that biodiversity gain would be considered on a project wide basis during design;

Solar panels and batteries are required, subject to further design; For solar panels 30% (average per year) of energy reduction has been assumed. This was applied to adjust the grid electricity factors.

The designs from the suppliers assume a constant flowrate of the desired 227 MLD from the process, as opposed to a set max, average and min flow. The process models are also based on this max flow.

For RGF options the steel structure has been assumed to use 30% of the carbon volume of concrete structure

Uncertainties and Sensitivity Analysis

We have used the Ofwat and WINEP valuations and have focused our attention on the metrics and the benefit profiles.

We have made conservative estimates for when benefits will start and finish, and how they increase and decrease over time. As such, our economic analysis is inherently conservative by nature. We then consider the benefit metric for sensitivity studies as this becomes the most material uncertainty in the analysis.

Within our spreadsheet we use the goal seek function to determine the value of a metric of concern that would be required to make the scheme cost beneficial. This provides a sensitivity check on the metric and enables commentary on the reasonableness of the economic analysis. We have run sensitivity checks on all significant benefit metrics

Third Party Assurance and Audit Trail

The study was carried out by our professional service suppliers Stantec, and their contractor Aqua, providing 3rd party assurance. Progress meetings and report and cost reviews were periodically undertaken by Affinity Water internal stakeholders and project team.

Option Assessment

Commentary on the Economic Assessment

		Option Definition	
Option 1:	Baseline	Baseline (Do nothing or maintain)	Baseline/Existing/Do Nothing
Option 2:	Core	Preferred Option	Existing Assets + RGF's [Location 2]
Option 3:	Alt 1	Least Cost	Existing Assets + RGF's [Location 1]
Option 4:	Alt 2	Alternative Option 1	Actiflo + RGF's [Location 1]
Option 5:	Alt 3	Alternative Option 2	Actiflo + RGF's [Location 2]
Option 6:	Alt 4	Alternative Option 3	Actiflo + RGF's [Location 3]
Option 7:	Alt 5	Alternative Option 4	Ceramic Membrane Plant
Option 8:	Alt 6	Alternative Option 5	Submerged Membrane Plant
Option 9:	Alt 7	Alternative Option 6	
Option 10:	Alt 8	Goal Seeking Analysis	Sensitivity analysis

Options	Total Investment	5 yr Investment	Total NPV	NPV Costs (Capex)	NPV Costs (Opex)	Total NPV Benefits	Cost Beneficial	Benefit / Cost
Option 1:	£ -	£ -	£ -	£ -	£ -	£ -	Yes	0.00
Option 2:	£ 77,601,156	£ 46,465,660	£ 49,130,845	-£ 40,926,152	-£ 6,575,238	£ 96,632,235	Yes	2.03
Option 3:	£ 76,142,071	£ 45,006,575	£ 50,388,540	-£ 39,668,457	-£ 6,575,238	£ 96,632,235	Yes	2.09
Option 4:	£ 195,357,250	£ 61,512,132	£ 6,766,209	-£ 52,143,018	-£ 37,723,008	£ 96,632,235	Yes	1.08
Option 5:	£ 195,034,830	£ 61,275,685	£ 6,980,775	-£ 51,928,451	-£ 37,723,008	£ 96,632,235	Yes	1.08
Option 6:	£ 195,962,606	£ 62,203,461	£ 6,181,055	-£ 52,728,172	-£ 37,723,008	£ 96,632,235	Yes	1.07
Option 7:	£ 356,538,880	£ 101,930,402	-£ 33,874,418	-£ 110,159,983	-£ 20,346,670	£ 96,632,235	No	0.74
Option 8:	£ 268,705,105	£ 61,897,510	-£ 1,609,565	-£ 62,414,968	-£ 35,826,832	£ 96,632,235	No	0.98
Option 9:							Yes	0.00
Option 10:	£ 95,463,270	£ 40,107,674	£ -	-£ 34,285,885	-£ 15,511,286	£ 49,797,171	Yes	1.00

The sensitivity analysis was carried out by applying a reduction factor that achieved a benefit/cost ratio of 1 [option 10 above].

Preferred, Best Value, Option

Option 2 Existing assets and RGF's [Location 2]

As the NPV table shows, Options 2 and 3 are significantly lower cost than all other options, both in the short term and over the NPV period. Sensitivity analysis shows that even with a reduction to only 15% of expected benefits the project will remain cost beneficial.

The only difference between Option 2 and 3 is the location, and the layouts created for this option showing the two possible RGF locations identified are shown in the previous section, with location 1 in the north-east of the site, and location two the south-east. The difference between the two is the ease with which future changes can be made to the treatment process and new units added. For instance, location one requires less new pipework and less intermediate pumping compared to location two but takes the space that may be required by a new treatment process in a later AMP. For this reason, the preferred option is to construct the RGFs in location two and use the more efficient location for any future process that is likely to be on site for a long time. Location 2 is large enough to accommodate the new RGF's and therefore was also in line with the objective to ensure any solution aligns with any longer term potential investments.

The need for re-lift pumping has been identified, and this poses an issue for the availability of power, which is dealt with by including for a solar power and battery facility to cope with additional peaks in demand, as well as potential for reducing power requirements in the wastewater treatment phase.

While a major overhaul of the wastewater system is not necessary from a process standpoint, given that the addition of RGFs will result in even more flow to the tank it is important that the wastewater holding tank be expanded, and that the sludge thickener capacity is increased to deal with the calculated hydraulic loading. The implementation of Evergreen's Volute thickeners could achieve this whilst easing the site's power issues. The unit has the advantage of being able to dewater and thicken sludge in one combined unit, which would reduce the footprint of the waste treatment process and eliminate the energy intensive centrifuges. Based on information supplied by the supplier, in a trial carried out for United Utilities (UU), it was found that Volute units showed up to an 80% reduction in power consumption compared to centrifuges, along with up to 10 times lower water consumption than a belt press. These potential savings, along with the fact that the technology has been implemented at scale within the UK (e.g., at United Utilities 30 MLD Williamsgate WTW), show that Volute could be an effective option to ensure the required power is available.

Least Cost Option 2

Option 2 Existing assets and RGF's [Location 1]

For the reasons stated in the previous section, despite the NPV being slightly lower than option 2, the potential cost saving against any future development of the site is expected to outweigh the £978k estimated difference between the two locations.

Alternative Option 3

Options 4, 5 and 6 are variations of the same option at different locations, which would include building a new actiflo to replace the pulsator clarifiers. This would be a long term commitment to the actiflo process, and was deemed not an essential component of meeting the DWI notice requirements. The existing clarification process can still be serviceable, and therefore purely from a cost perspective this option could be ruled out. The other key factors also supporting these options being ruled out are removing the additional carbon impact, and the better value for customers achieved from maximising the life of the existing assets.

Alternative Option 4

Ceramic membrane

This option was the highest cost, with risks associated with the unknown performance, and would also be a long-term investment decision affecting many parts of the Iver treatment works.

This option was considered to involve significant risk in that the performance when used with the raw water quality at Iver could not be verified. As a relatively new process there is no guarantee that the membranes will perform effectively when dealing with the types of algae present in the Thames. Additionally, the potential for Volute technology previously highlighted in Section 3.1 may be severely limited for ceramic membranes. Based on the case studies provided on its use in UK treatment works, significant doses of polymer are required. Thus, the technology may be incompatible with ceramic membranes.

Changes to the dosing systems would also be required when installing ceramic membranes. For instance, inline coagulation could result in a significant decrease in coagulant dose over conventional treatment, which is driven in part by forming a settleable floc. As well as this, polyelectrolyte dosing can be entirely removed from the clarification stage and potentially the wastewater treatment stage too. The process modelling was constructed under the assumption that a similar thickener performance can be achieved even without polymer dosing. This is a significant risk as there is currently a lack of concrete evidence available to support this assumption, as while facilities such as Mayflower WTW do not require polymer dosing in lamella plate thickeners, the performance of WRc style thickeners is unknown. Piloting and settlement tests would be essential to confirm whether this is the case, as a major rework of the waste system could be required if it turns out to not be the case to avoid very wet sludge and poor supernatant.

Alternative Option 5

Submerged membranes

Many similarities with the ceramic membrane option, although a tried and tested treatment. This was the second highest cost option, and also would be a long-term investment decision affecting many parts of the Iver site.

Meeting Affinity Water's Outcomes

To facilitate an effective and efficient process to look at the implications of the PR24 Business Cases on carbon (operational and embedded), biodiversity, including Biodiversity Net Gain and Natural Capital all Business cases were screened with relevant Business case leads to ascertain where there was potential for material impact on Carbon, Biodiversity or Natural Capital. Once the potential for an impact was identified the significance associated with that impact was explored with relevant specialists and business case leads.

Surgery sessions were held with business case leads to set out considerations for each of the three assessment areas. Criteria to assess significance of carbon impact included:

· A material increase or decrease in operational CO2 emissions and/or

· An impact on capital carbon, e.g. identification of requirement for a physical build or change in capital maintenance resource use

Both the embedded carbon (resulting from construction activities) and operational carbon (resulting from energy and chemical use) were assessed

Stantec analysed the carbon costs for each option using their carbon tool, shown in the table below.

Option	Embodied Carbon Emissions (tCO_2e) – *from construction*	Annual Operational Carbon Emissions (tCO_2e/yr)	Cumulative (Whole Life) Carbon Emissions (tCO_2e)
1 – Baseline (Do Nothing)	0	23,876	960,707
2 – Existing Assets + new RGFs (in location 1)	3,192	22,387	852,040
3 – Existing Assets + new RGFs (in location 2)	3,862	22,387	852,709
4 – Actiflo + RGFs (in location 1)	6,980	24,601	1,009,125
5 – Actiflo + RGFs (in location 2)	7,146	24,601	1,012,807
6 – Actiflo + RGFs (in location 3)	8,915	24,601	1,014,547
7 – Ceramic Membrane	2,441[1]	13,951[1]	348,347[1]
8 - Submerged Membrane	N/A[2]	N/A[2]	N/A[2]

Ceramic membranes were shown to be the lowest whole life carbon impact, however that option was ruled out for the reasons explained in the previous section. Also, the carbon assessment did not consider demolition and decommissioning of the assets that would be made obsolete earlier than their forecast end of life.

Of the remaining options, using the existing assets alongside the new RGFs was considerably lower than the alternatives.

Justification of the Preferred Option

The preferred option - Existing Assets + new RGFs (in location 2) - is supported by the economic analysis due to the favourable NPV, having marginally the second lowest capex expenditure with the potential for future cost savings, and of the affordable options having the joint lowest carbon impact.

This option achieves the objective of meeting the requirements of the DWI notice at the best value for customers, reducing risk by using known technology and maximising the life of existing assets.

The sensitivity analysis indicates the project remains cost beneficial at just 15% of the expected benefit to site output, a wide margin that gives high confidence the investment will deliver the customer benefits.

Delivery Considerations

Related Projects

The project is related to the Regulation notice also issued with regard to Egham WTW and similar cryptosporidium risk regarding that plant.

Lessons Learnt

Currently we are undertaking the UV installation and lessons with regard to power supply have been included.

Further review of GAC upgrade taken in 2016-18 to be carried out and lessons incorporated into the definition and implementation stages.

Delivery Risk Management

In December 2024 we will submit our final option for Iver Water Treatment Works as per the section 28 notice. At this stage we will need to commence detailed design and build of the solution to meet the 2027 completion date. The installation of RGFs is a large civils installation with a long lead into designing the solution and an anticipated build of 18-24 months which means construction will need to commence on day one of AMP8. Early contractor engagement and outline design has commenced, as well as early contractor involvement to ensure the design produced is both deliverable and affordable. A design and build contract is to be awarded in 2024 to ensure the programme is deliverable by the notice date. A dedicated programme team is being designed to deliver the Iver/Egham schemes and other surface works treatment schemes. This will focus the attention on delivery of these key projects.

Planning permission will be required for the solution. Recently we have seen an increase in planning constraints applied to approvals. Early engagement with the planning authority will be required through the pre-application process to address these early.

One specific risk that has been identified is having sufficient power supply available for the project. The existing works has a limited hydraulic gradient, and any introduction of head loss will require a pumping station, increasing the power required. The grid capacity for further increases is limited and unlikely to be increased prior to 2028 leaving a potential deficit.

There is not an option available that avoids this need. The mitigation has been included in the development of options, and includes building solar panels and battery storage into the design, as well as finding ways to minimise power requirements such as with the use of efficient technology when upgrading the wastewater capacity. An alternative mitigation would be to rely on adding diesel generation to the scope, but this is seen as more expensive over the whole life costs due to the cost of diesel, as well being less environmentally acceptable, thus not fitting with our company environment and net-zero ambitions.

Further detail regarding how we have ensured the deliverability of our full investment portfolio is provided within AFW 32 Deliverability of our Plans.

Monitoring and Reporting of Benefits

The project must be delivered in line with the DWI notice date of Dec 2027, and will be achieved by delivery through project gateways and milestones. The DWI under the statutory notice require us to report at different stages to ensure that we are on track with delivering the intended outputs as laid out.

Affinity Water

Egham Surface Works (DWI)

September 2023

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Summary

The Drinking Water Inspectorate (DWI) has issued a Section 28(4) Notice which includes the requirement to improve treatment at the site and if the company fail to comply it may result in enforcement proceedings under Section 18 of the Water Industry Act 1991. The new treatment is to address the risk of supplying water that could constitute a potential danger to human health from the presence of Cryptosporidium oocysts in the River Thames water. Ingestion of these oocysts by humans can lead to severe diarrhoea and vomiting, which can be life-threatening for individuals with a weakened immune system.

The notice describes that Affinity is to design, construct, commission additional treatment options, or modifications to existing treatment and include:

1. A validated UV irradiation system for the inactivation of Cryptosporidium oocysts (delivery AMP7).
2. Optimisation of the clarification process.
3. Upgrade of the RGF process
4. The upgrade of the wastewater treatment plant to improve water recirculating to the head of the works.

Item 1 is being delivered in AMP7, and this business case describes the optioneering process that has been completed to ensure items 2, 3 and 4 are addressed with the optimum investment considering the timescale and future requirements for the site. The selected option represents the best value both in terms of the lowest initial capital expenditure and in line with our long-term delivery strategy.

Affinity Water

Project Details

AMP8 Spend	2025-26	2026-27	2027-28	2028-29	2029-30	Total
Capex (£m)	5.69	5.69	2.84	0.00	0.00	**14.22**
Opex (£m)	0.00	0.00	0.19	0.39	0.38	**0.96**
Totex (£m)	5.69	5.69	3.03	0.39	0.38	**15.18**

Drivers	
100%	Addressing raw water quality deterioration (grey solutions)

Benefits
Loss of Production Capacity (Ml/d) Compliance Risk Index (score)

Economic Analysis			
NPV Costs (£m) (2025-55)	**19.7**	NPV Benefits (£m) (2025-55)	**52.9**
NPV (£m) (2025-55)	**33.2**	Benefit / Cost Ratio	**2.7**

Six Capitals

Natural	Social	Financial	Manufact.	Human	Intellectual
	★ ★ ★	★	★ ★		

Project Description

The Drinking Water Inspectorate (DWI) has issued a Section 28(4) Notice which includes the requirement to improve treatment at the site and if the company fail to comply it may result in enforcement proceedings under Section 18 of the Water Industry Act 1991.

The notice sets out a number of steps that Affinity is required to take to mitigate a significant risk of supplying water that could constitute a potential danger to human health or could be unwholesome. The new treatment is to address the risk from the presence of Cryptosporidium oocysts in the River Thames water. Ingestion of these oocysts by humans can lead to severe diarrhoea and vomiting, which can be life-threatening for individuals with a weakened immune system.

The DWI have detailed a number of steps that Affinity Water needs to take at Egham to ensure that this risk is mitigated now and in the future. The notice describes that Affinity is to design, construct, commission additional treatment options, or modifications to existing treatment and include:

1. A validated UV irradiation system for the inactivation of Cryptosporidium oocysts (delivery AMP7).
2. Optimisation of the clarification process.
3. Upgrade of the RGF process
4. The upgrade of the wastewater treatment plant to improve water recirculating to the head of the works.

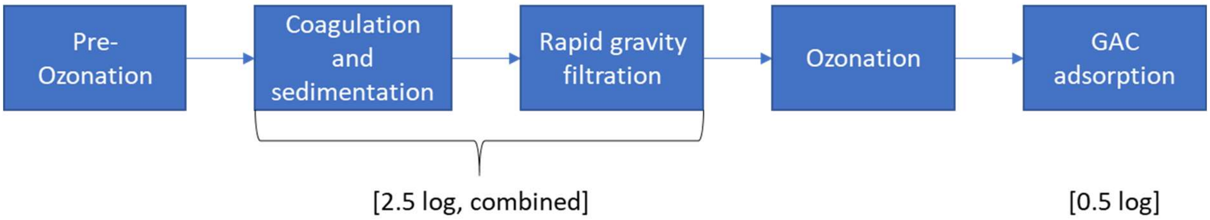
The design of these works (exc. UV) will need to be complete by November 2024 and, the construction and commissioning to be complete December 2027.

Project Development

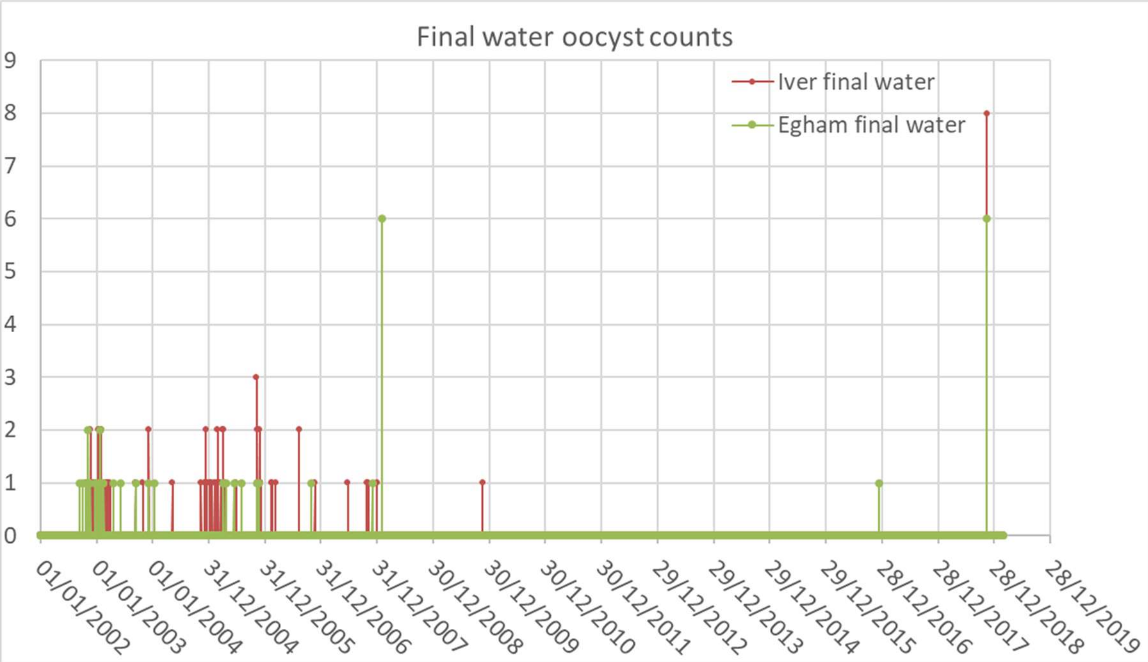
Baseline Assessment

The treatment process chain at Egham WTW comprises direct river abstraction (with partial blending from Queensmead Lake), pre-ozone dosing, coagulation and sedimentation, rapid sand filtration, inter-ozone dosing, GAC adsorption, UV irradiation and disinfection with chlorine.

The treatment processes at Egham meet the industry-standard approach for solids removal, where the clarification stage is followed by dedicated filtration. However, 3-log removal of Cryptosporidium can only be achieved at 120Ml/d if water quality is good. We have operated at higher flowrates where operational emergencies dictated, and we also reduce flow when raw water quality deteriorates to maintain that level of removal. At the flows required to satisfy our supply-demand balance (140Ml/d from 2030) we will not be able to guarantee a robust 3-log removal with the existing treatment processes.



The graph below shows Cryptosporidium oocyst detection in the final water at Iver and Egham since 2002. Since between 2007 and 2018 there was only one incident on each works of final water oocyst detection and neither event was reportable. It is possible that with changing weather patterns due to climate change, long dry periods in the summer followed by sudden heavy rainfall and 'first flush' events, the incidents of high Cryptosporidium concentration in the River Thames could increase.



Whilst we describe our treatment processes as robust, we also know they are not absolute, and that a level of risk remains should the concentration of Cryptosporidium oocysts in the river water peak at very high concentrations.

Problem Statement and Stated Need / Driver

The Drinking Water Inspectorate (DWI) has issued a Section 28(4) notice which includes the requirement to improve treatment at the site and if the company fail to comply it may result in enforcement proceedings under Section 18 of the Water Industry Act 1991. This was in response to an event 'Cryptosporidium detection at Iver and Egham Water Treatment Works November 2018 (DWI Ref: 2018/6901)' outlined below.

Samples taken between 10th and 11th November 2018 from Iver WTW and Egham WTW detected Cryptosporidium oocysts in the final water from each site. The risk posed by Cryptosporidium oocysts is that their ingestion by humans can lead to acute cryptosporidiosis causing severe diarrhoea and vomiting, which can be life-threatening for individuals with a weakened immune system.

There was a risk that we would need to impose a Boil Water Notice (BWN) to 1.2m Affinity Water customers (including Heathrow Airport) and 0.1m South East Water customers to protect them from these health impacts. Subsequent samples were fast tracked through the laboratory, and we were able to confirm that this was a short-lived event and no BWN was required.

We engaged immediately with multiple agencies across our company area to keep them updated on events; Public Health England Health Protection Team, Local Authority, Environmental Health Teams, CCWater, Water Security and Resilience team at Defra and Drinking Water Inspectorate (DWI). We also engaged with the Environment Agency (EA), Thames Water Utilities (TWUL) and South East Water (SEW).

TWUL confirmed that there had been no operational issues with any of their sewage treatment works that discharge into the River Thames, or its tributaries, upstream of our abstraction points. This is supported by the fact that the species of oocysts identified was Cryptosporidium Parvum, which is not specific to humans, so the source could have been human or animal. The EA confirmed that there was no pollution report linked to the event in the relevant parts of the Lower Thames catchment leading up to the Cryptosporidium detection.

To date we have found no obvious cause of the high concentrations of Cryptosporidium oocysts in the raw water, but investigations have modelled a deterioration in river water quality around the Maidenhead area, and a point source pollution is suspected. It is unlikely that the source of this particular pollution event will be identified now but there is still a need to identify catchment risks and engage with those stakeholders.

An initial investigation report was submitted to DWI and follow up report (20 day) with greater detail was submitted 7 December 2018. We received an event assessment letter from DWI on 14 March 2019 and we received a Notice from DWI on 18 April 2019.

Whilst we describe our treatment processes as robust, we also know they are not absolute, and that a level of risk remains should we encounter further gross pollution events. As a result, we have considered several options for managing and mitigating the remaining risk, investigating the feasibility, timescale, level of risk, and approximate costs associated with each.

Risks, Issues and Requirements

Our statutory obligations in relation to water quality are contained in section 68 of the Water Industry Act 1991 and the Water Supply (Water Quality) Regulations 2016 ("Water Quality Regs"). Section 68(1) of the Water Industry Act 1991 provides that a water undertaker has a duty in relation to water supplied for domestic or food production purposes:

> a) to ensure that any water so supplied is wholesome at the time of supply; and,
> b) so far as reasonably practicable, to ensure, in relation to each source of combination of sources from which water is supplied, that there is, in general, no deterioration in the quality of water which is supplied from time to time from that source or combination of sources.

Water is "wholesome" if it meets the standards prescribed in Regulation 4 of the Water Quality Regs, including the following requirements, among others:

> a) that the water does not contain
> > i. any micro-organism (other than a parameter listed in Schedule 1) or parasite, or

ii. any substance (other than a parameter listed in Schedule 1), at a concentration or value which would constitute a potential danger to human health.

To provide adequate solids removal at Egham, under challenging raw water quality conditions, we currently reduce flow through the works to reduce the likelihood of Cryptosporidium oocyst breakthrough. This ensures that we can maintain the wholesomeness of drinking water in the areas receiving water from Egham.

As we shift our abstraction away from the chalk groundwater sources in favour of maximising the use of surface water to protect the chalk stream environments, in line with the LTDS Core Pathway approach on Abstraction Reduction, we will experience changes in the supply-demand balance in these communities it will not be possible to continue to do this in the future. The Core Pathway for WRMP requires the surface water treatment works to produce water reliably, at 227Ml/d for Iver and 140Ml/d for Egham.

We also need to consider the requirement in section 68(1)(b), which relates to deterioration in the quality of water supplied to customers. It provides two overarching principles in relation to this duty:

- that the company should not expose consumers to a greater risk of exposure to unwholesome water; and
- that the company must always plan to meet its water quality obligations (paragraph 4.3.3).

If we were to supply water from Egham treatment works at the full site flow capacity without enhancing the level of treatment provided, we would be exposing our consumers to a greater risk of receiving water that is unwholesome and in doing so we would be knowingly risking not meeting our water quality obligations.

The DWI Guidance explains that the standard of no deterioration should be measured by reference to compliance with the standards of wholesomeness (paragraph 4.3.6) specifically:

The Inspectorate interprets the statutory requirement for ‘no deterioration’ by reference to compliance with the requirements of the Regulations, including standards. A marginal change in the concentration or level of a parameter may not be considered as deterioration if the water as supplied remains wholesome and is acceptable to consumers, provided that the company can demonstrate that it has considered and limited the deterioration as far as is reasonably practical to do so.

The provision of enhanced treatment at Egham treatment works is a mitigating measure that would enable us to provide adequate pre-treatment of water fed to the UV reactors for Cryptosporidium inactivation when higher flows from these works are required. The works would do this by ensuring that we are meeting the industry standard best practice level of treatment for Cryptosporidium, under all flow and typical raw water quality conditions. Delivering this work will also demonstrate that we have “considered and limited the deterioration” due to increasing flows through the treatment works as far as is reasonably practical.

Allocation of Costs

Due to the improvement in the site and its subsequent future performance the costs associated with the DWI notice letter would be deemed as enhancement.

As the graph 'final water oocyst counts' in the baseline assessment section shows, the event leading to the DWI notice was at a higher level than previously experienced, and as such requires a step change in our treatment process and ability to cope with such events.

An exercise was carried out to ascertain whether there would be any overlap with Base costs in AMP8. The majority of the scope required by the solution detailed in this business case is related to building additional treatment in the form of increased capacity in the RGF filtration stage, and therefore will not have any overlap with existing base capital maintenance activity. Other parts of the scope relate to improvement of the clarification process, and increasing capacity of the wastewater plant on site, the method by which this is achieved to be verified using pilot trials.

Pioneer is used to model predicted costs based on asset deterioration models, and this was analysed for the potential AMP8 intervention costs in these two areas. There are no significant planned or reactive costs forecast in the model.

An assessment of existing issues was also carried out to determine if they would have required investment in AMP8, and if the scope of this project would address them. Part of Stantec's initial work was an assessment of the existing assets, which included a visual report on the clarifier assets. The findings were that the assets were in sound condition, and the metal components were in sound visual condition with no evidence of degradation.

Upgrade and modifications of the wastewater process are necessary to deal with the increased capacity. Although a major overhaul of the existing wastewater treatment is not necessary from a process standpoint, the implementation of Evergreen's Volute thickeners could offer the advantage to dewater and thicken sludge in one combined unit, which could reduce the footprint of the waste treatment process onsite and eliminate the energy intensive centrifuges. There are no base costs being addressed as part of this enhancement funding in the wastewater part of the scope. None of the scope items detailed in the preferred option has been previously funded in earlier AMPs.

DPC

Direct Procurement for Customers (DPC) is not applicable to this investment as it falls below the cost threshold of £200m.

Research, Pilots, and Technology Development

Initial optioneering focussed on tried and tested technologies for the water treatment options, but at a later stage the more recent development of ceramic membrane technology was included for appraisal. A site visit to a ceramic membrane in operation at South West Water's Mayflower WTW was undertaken by a team from Affinity water to understand the potential suitability for use at Iver or Egham.

Relating to the need to increase waste treatment capacity in line with the preferred solution, the actual method is yet to be agreed. Volute dewatering has been proposed as an alternative to expanding the existing process, but due to unknowns with the performance with the particular water quality at Egham, piloting will be an essential step before any implementation of the technology.

Customer Engagement

Detail of Customer Engagement work

We have undertaken extensive engagement with our customers to build a detailed understanding of their priorities and reflected these in this business case. For more detail on our customer engagement see AFW04 What Customers and Stakeholders Want.

We carried out some customer engagement, [1,2,3,4] as part of the Strategic Resource Options programme of work, looking at how customers preferred to be communicated with. This gave us the opportunity to gain some insights into their thoughts and preferences about several of the long-term plans related to water resourcing, including source types.

An evidence review was carried out of 50 documents and stakeholder interviews with each of the water companies, with documents gathered directly from the 6 water companies involved in WRSE, and the evidence was then synthesised to identify consistent findings which were triangulated to assess their strength. During the qualitative phase we tested these findings with 96 household customers across the 6 companies, including Gen Z and vulnerable customer. During the quantitative phase we held 15-minute online surveys with 1,762 household and 198 non-household customers for robust segmentation and validation of findings.

This research reinforced our understanding that water is a low salience topic with our customers, in that they have a low level of awareness and understanding of issues relating to it. This in part is driven by general satisfaction with the customer experience of water in terms of taste, smell and hardness.

We followed this up with some deep dive sessions in July 2022 to specifically test on our own long-term plans with a wide cross section of our customer base[5]. 82 customers and 10 business representatives participated in this research. Customers were divided into 'household', 'vulnerable' and 'future' groups to reflect a range of views, whilst local business representatives provided views on behalf of their place of work ('Non-household').

The Non-household individuals were recruited from businesses which are heavy water users. Customer groups covered a range of ages, socio-economic backgrounds and areas within Affinity Water's region in order to enable a diverse range of views. Given the long-term focus of the research, future customers were also included to gauge an understanding of priorities from individuals who are likely to become Affinity Water customers in the future.

[1] WRSE Customer Preferences_Part A Evidence Review_Final Report_eftec ICS_February 2021.pdf
[2] Water Club - Changes of Source - June 2022.pdf
[3] Affinity Water Customer Valuation Research Summary Report May 2023.pdf
[4] Affinity Water Customer Priorities for Long-term Ambitions
[5] 'Customer Priorities for long-term ambitions to support PR24 and long-term delivery strategies,' September 2022

Ten online focus groups were held (household and future customers) and fifteen one-to-one interviews conducted (vulnerable and non-household customers). Focus groups were conducted via online video, using the specialist VisionsLive platform, each session lasting 90 minutes. Voting exercises and activities were used throughout the focus groups, to aid engagement, capture strength of feeling, and focus the discussion on the core research questions.

These were qualitative sessions and the outcomes gave us some insight into customer views of the relative importance to them of, among other considerations:

- Reducing amount of chemicals used in water treatment,
- Reducing carbon emissions associated with treating water for customers,
- Hardness level of their water supply, and
- Keeping customer bills as low as possible.

Finally, we held some quantitative research sessions between February and March of 2023 with a second set of workshops looking at Customer views on priorities covering customer preferences for changing service levels. Customers were generally observed to be more sensitive to avoiding deteriorated service levels compared to the preference for improvements. In general, there was a limited preference for changes in service levels for hard water and hosepipes bans.

911 household customers completed the survey between February and March 2023 800 respondents completed an online survey and 111 completed an in-person interview, qualifying as "digitally disengaged." 42% of the household respondents (383 people) were classified as being in vulnerable circumstances. Around 13% of respondents who took part in the study (117 people) were registered with the Priority Services Register. Of these 117 respondents, 31% were medically dependent on water, 56% suffered from physical issues, and 9% need information in alternative formats.

There was a good distribution among the respondents of all targeted characteristics. Females were slightly over-represented (57% of respondents) and were within +/- 7 percentage of sample quotas. Socio-economic group (SEG) profile were within +/- 3 percentage points of sample quota. All age cohorts were within +/- 4 percentage points of sample quotas.

150 non-household (NHH) respondents completed the survey online. These comprised a good mix of NHHs achieved when measured by both number of sites and by number of employees. Around a third of organisations had only 1 site (34%), 12% of respondents were a sole trader and 15% of respondents had between 100-150 employees. Also, the sample distribution by economic sector has the expected profile with 1% as Primary, 28% as Secondary and 71% as Tertiary.

Evidence of Customer Preferences

We have developed all of this research and analysis into a document called 'What our Customers & Stakeholders Want[6]' which presents the findings from the various customer engagement activities. The key takeaway point from the research is that customers have a high level of inherent trust in us as a water provider, and generally are happy for us to make decisions about technology selection and water quality risk management without consultation with them – we are the experts, and they trust us to make those decisions.

Another outcome of the research was a strong steer that customers expect us to meet our regulatory duties at all times, with respect to the Water Supply (Water Quality) Regulations. Any strategic decisions we make with respect to cost or carbon emission reduction must not have any detrimental impact on water quality performance.

The outcomes from the deep-dive qualitative sessions with our own customers indicated that they have wide ranging responses to the questions of whether we should be reducing chemical use in water treatment and whether we should be reducing operational carbon emissions, which could be influenced by many factors including the respondents' own socio-economic group, with no overall preference or point-of-view expressed[7]. Two thirds of customers did not support investment to soften hard water, with a third supporting investment. Hard water tends to polarise customer opinions. However, there was a clear steer from customers, from these qualitative sessions, that their main priority over any of the other considerations was to keep bills as low as practicable.

The SRO customer communication preferences work indicated that there are some acceptance barriers in place for customers around some of our water resourcing ideas, particularly with respect to direct or indirect wastewater effluent reuse schemes. They indicated that they would need reassurance if this type of approach were taken that water would be safe to drink.

The qualitative research sessions indicated that customers were generally observed to be more sensitive to avoiding deteriorated service levels compared to the preference for improvements. Household customer values for improved service levels for areas including tap water aesthetics was relatively modest – but nevertheless improvement in these areas was viewed as beneficial. In general, there was a limited preference for changes in service levels for hard water and hosepipes bans. Respondents felt that Affinity Water's services are good value for money and were generally satisfied with the services they receive.

Customer protection

Customers will be protected through a Price Control Deliverable for this project, which will be aligned with the requirements set out by the DWI in the Section 28(4)

[6] What our Customers and Stakeholders Want V5 final.pdf

[7] Line of sight V2.docx

Notice. The PCD will cover all the benefits that we propose to deliver under the requested funding.

There will be no third-party funding or delivery arrangements as part of this work.

Partnering

Collaboration and Partnering

Engagement with Stakeholders and Partners

Stantec, one of Affinity Water's Professional Services Partners was engaged to carry out a strategic assessment of the options for the development of Egham Water Treatment Works. The Stantec project team worked closely with Affinity Water stakeholders to understand the current site treatment processes and condition, the need relating to the DWI notice, and checked in at various stages through the assessment and optioneering process.

During optioneering, engagement commenced locally and with regulators as set out in the DWI notice.

Stantec engaged the services of Aqua Consultants, commercial engineering consultants with particular experience of the water industry, to produce cost and carbon estimates. Aqua hold a mature and extensive database of estimating material. Cost estimates have been prepared using a combination of cost models and unit costs based on experience within the Water Industry, through AMP7 and AMP6, PR19 and PR24 as well as budget estimates from the market.

<u>Drinking Water Inspectorate (DWI).</u>

The DWI under the statutory notice require us to report at different stages to ensure that we are on track with delivering the intended outputs as laid out.

In December 2024 we will submit our final option for Egham Water Treatment Works for the list deliverables as per the section 28 notice. At this stage we will need to commence detailed design and build of the solution to meet 2027 completion date.

<u>Environment Agency</u>

As part of the scope is to determine option for the run to waste facilities of the site. This is detailed in the relevant business case and not discussed further here.

Co-design and Co-delivery

Currently, we are commencing on a strategy whereby the optioneering for the outline design is being carried out by one of our partners Stantec. As the same time to ensure constructability and appropriate construction budgeting is taking place we will engage with our larger construction partner Galliford Try in early contractor involvement (ECI) to assure that what is produced is both deliverable and affordable.

Strategy Development

All of our enhancement cases have been developed as part of our integrated investment portfolio that takes the first steps of our Long Term Delivery Strategy and achieving our ambitions as laid out in AFW03 Strategic Direction Statement.

Long-term Delivery Strategy Alignment

In our Strategic Direction Statement[8] we commit to "Deliver what our customers need, ensuring affordability for all" which encompasses "Exceed[ing] customers' expectations for drinking water." Our customer consultation work has confirmed that customers hold inherent trust in us to make the appropriate interventions to safeguard their water quality.

There is an additional commitment to "Be prepared for change and resilient to shocks and stresses" within which we commit to "Ensure a resilient supply of water for Affinity Water customers." We are delivering on this commit in this case by providing treatment where no blending or other management of the risk is possible without detrimental effect on the resilience of our supply.

Our long-term delivery strategy related to water treatment includes an investment line covering "Addressing raw water deterioration." We have delivered multiple workstreams to address the risk from Cryptosporidium at the source in our catchments, with further information on this in the optioneering section.

An optioneering study has been completed with Stantec, one of our Professional Services Partners and this will ensure the following has been considered;

'In addition to the satisfying the DWI requirements with respect to Cryptosporidium risk the key project drivers include the following requirements to be considered by the Consultant:

- Maximise the utilisation of existing infrastructure.
- Reduce net operating expenditure.
- Reduce net operational carbon footprint.
- Minimise embodied carbon footprint.
- Ensure relevant installations and construction works are within the existing site boundary.'

These align with our long term commitment and the output of the outline design will then be used to construct the necessary environmental strategy for the construction phase.

The investments proposed within this business case are aligned with the Core Adaptive Pathway for Egham WTW in our LTDS and will not adversely impact any of the potential

[8] AW0031_Strategic-direction-statement.pdf

Alternate Pathways identified. The investments will still be required under all common reference future scenarios.

Treatment Strategy

Currently, our Treatment Strategy requires provision of treatment only when necessary due to raw water quality and when it is the best value holistic solution to provide treatment rather than any other solution.

We are exploring options around selection of the final options for the DWI deliverables and the criteria above. These key criteria will enable the successful delivery of the project within the tight timescales. These align with the current investment strategies.

The WRMP strategy clearly requires a baseload performance at Iver and Egham post-AMP8 in order to maintain the supply-demand balance in the Central region. It is essential that the two treatment works can provide 227Ml/d and 140Ml/d respectively for a prolonged duration to enable the water supply strategy, and this investment is critical to enabling this.

Adaptive Strategy

A project steering group has been setup from WQ, Asset Strategy, Capital delivery and Operations to ensure ideas/issues/challenges are discussed from all perspectives to ensure robust challenge from all parties to satisfy our strategic goals for the project.

This project is no regrets because we require the water from the sources to meet our supply demand balance and, without the investment at Egham, we predict we will otherwise need to reduce its output in AMP8 when river water quality deteriorates.

While the DWI notice gives a compliance date of 2027 for the upgrade of the filtration and wastewater processes, the aim of this project was to take a longer view for the site, extending past AMP 8 into AMPs 9 and 10. There is an acknowledgement that it may not be feasible to carry out all of the changes required in a single AMP, so short term changes may be required which are then subject to change at a later date. Therefore, the solution derived from the project was to meet the short-term regulatory challenge, while still enabling Affinity Water to keep options open for future development. The results of the optioneering have been appraised to ensure the preferred option fits with the medium term outlook, and that investments will not be made obsolete by site enhancements in the near future. Furthermore the customer will be protected with Price Control Deliverables (PCD's) in line with the DWI notice commitments

Optioneering

We have consistently proposed best value solutions using rigorous optioneering. For more detail on our approach is provided within AFW08 Our Investment Development Process.

A full optioneering report was submitted to the DWI in 2019 detailing the catchment, the current treatment process onsite and the options to deal with future pollution events with regard to Cryptosporidium. An internal workshop was held to brainstorm all conceivable options that could mitigate a repeat of the incident in 2018, and the table below details these unconstrained options. This next step in this approach was to screen out any unfeasible options, whether due to lack of efficacy, space, or time to implement and take effect – thus any of the unconstrained options that would not fit, could not be built in time, or were not effective in meeting the requirements were discounted.

TREATMENT OPTION	SPACE	TIME	EFFICACY	INCLUDE
Do nothing	G	G	R	Y
Catchment management	G	A	A	Y
Alternative raw water source	G	A	R	N
Blending raw water	G	G	R	N
Optimisation of assets	G	A	A	Y
Bank side storage	R	R	A	N
UF membranes	A	A	G	Y
UV	A	A	G	Y
SSF (slow sand filters)	R	R	A	N
RGF (new rapid gravity filters)	A	A	A	Y
High rate clarifiers	G	A	A	Y
Blending final water	A	A	R	N

We have delivered multiple workstreams to address the risk from Cryptosporidium at the source in our catchments and updated our business as usual approach to catchment management following the incident in 2018 to incorporate review of satellite imagery to identify potential hotspots for risk. We have also rolled out online water quality monitoring on the River Thames upstream of our abstraction points to give early warning of potential pollution or high-risk events, allowing site operators to take appropriate mitigation action. It is not possible, however, to monitor presence of Cryptosporidium in real time so these monitors can only partially mitigate the risk by identify high-risk 'scenarios' on the river, *e.g.*, high turbidity events.

Due to the large size of the River Thames catchment, the number of land-users and stakeholders who could impact the river quality and the impracticality of carrying out land use assessments over the whole area, all of this intervention is not sufficient to adequately reduce the risk of Cryptosporidium oocysts presence in the final water at either treatment works. The catchment management plan was agreed to occur alongside any treatment options.

A number of the site options were developed for Egham WTW, in close collaboration with colleagues from Production to ensure that they were practical, complete, operable and feasible. These options are:

1. UV irradiation post-GAC only;
2. Upgrade of conventional treatment processes on site, in line with industry best practice;
3. Upgrade of conventional treatment processes on site, with UV post-GACs; and
4. Upgrade of conventional treatment processes on site, with ultra-filtration membranes post-GACs.

The advantages, disadvantages and risks were discussed for the 4 options. However, the DWI determined what it wanted to be delivered within its section 28 notice.

This resulted in the AMP7 project to install UV at Iver and Egham with the understanding that the other options would be further developed for a subsequent phase.

Work to meet the additional AMP8 requirements in the notice continued with planning for further enhancements and began by engaging Stantec to develop the treatment options, following the steps shown in the timeline diagram below.

The brief given was to assess options to meet the DWI notices, but also included the need to take a longer term view, extending past AMP8 into AMP9 and 10 and ensuring any investments fit within the long term outlook for the site. This approach enables adaptive planning when considering future developments.

In the Phase 1 Egham Strategic Options Assessment, through site visits and discussions with Affinity Water, various high-level options were identified to improve and optimise the site to meet DWI requirements. Matched-Paired Analysis and CAPEX estimates were evaluated and used to compare the various options. Alongside this a detailed assessment of the existing site capabilities was undertaken.

A workshop was used to narrow down and assess the viability of five process options.

The five options identified to be studied further were:

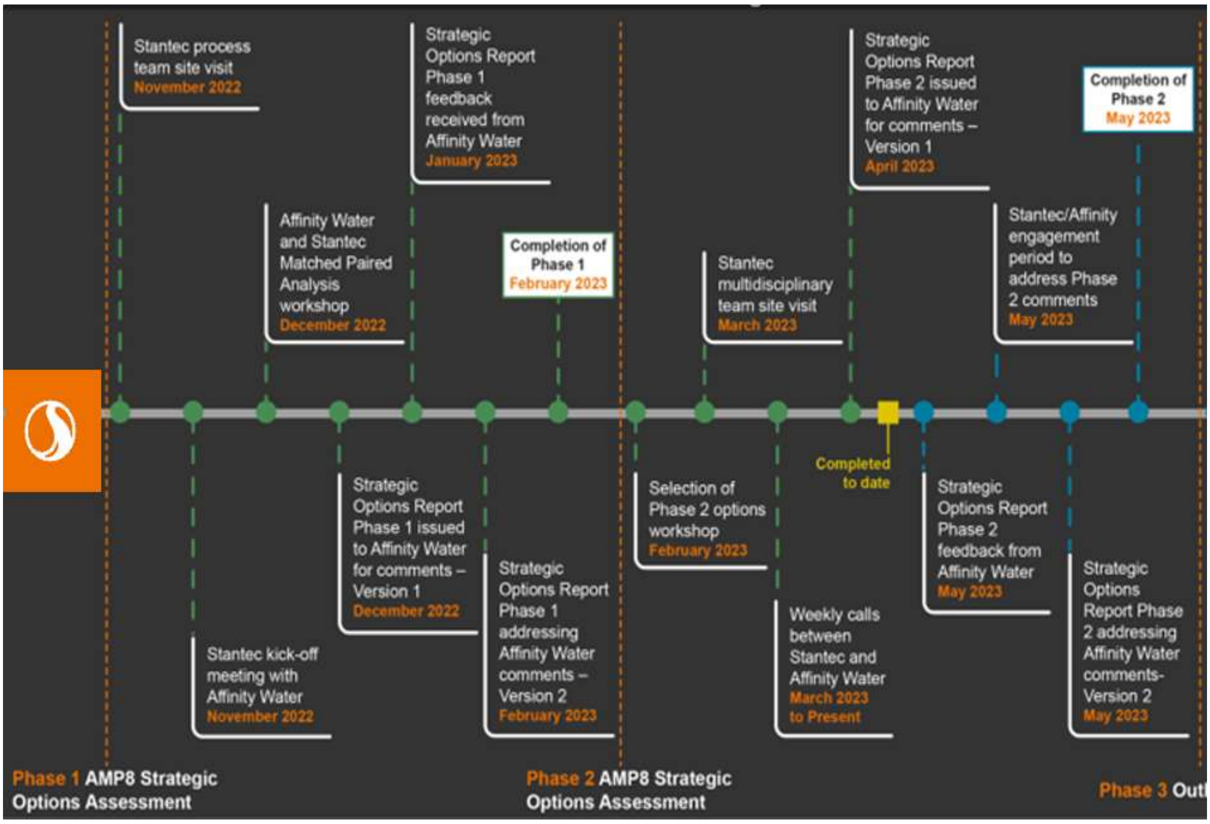
- Optimising the existing plant while adding an additional RGF house.

- Replacing the FBCs with an Actiflo while adding an additional RGF house.
- Replacing the FBCs with an Actiflo and replacing filter houses 4 and 5 with new set of filters.
- Replacing the FBCs and filter houses 4 and 5 with submerged membranes.
- Replacing the FBCs and filter houses 4 and 5 with ceramic membranes.

Phase 2 then further investigated and developed these options. To understand the effects of raw water quality deterioration on the treatment ability of the proposed options at Egham, raw water quality data provided by Affinity Water was analysed and used to set a design envelope which was then given to suppliers.

This envelope was also used to model each option using a modified version of the Affinity Water MIMIC_Egham_v3.0 model, a new model was created for each of the five proposed treatment processes. Through discussions, it was decided to design around the maximum analysed raw water quality data sampled from the river Thames, as opposed to the more commonly used 95th percentile. This was done to consider the effects of climate change, and account for future deterioration of the raw water quality to ensure that the proposed design has in-built resilience.

Continued development of the options included sub-options for different locations on the site, and construction materials of the filters. Stantec engaged in consultations with suppliers and stakeholders such as Nanostone, Veolia, SUEZ, and Evergreen Water Solutions and AQUA consultants. Environmental assessments, carbon calculations, and costings were carried out during this stage, and this work enabled qualitative and quantitative comparisons of the options.



Selected Options

For clarity, the option numbers will be referred to as they appear in the Strategic Options Report by Stantec, as per the table below:

Option 1:	Baseline/Existing/Do Nothing
Option 2:	**Existing Assets + 1 RGF House**
Option 3:	**Actiflo + Additional RGF's**
Option 4:	**Actiflo + New RGF's [Concrete]**
Option 5:	*Actiflo + New RGF's [Steel]*
Option 6:	**Ceramic Membrane Plant**
Option 7:	**Submerged Membrane Plant**

Option Definition			
Option 1:	Baseline	Baseline (Do nothing or maintain)	Baseline/Existing/Do Nothing
Option 2:	Core	Preferred Option	Existing Assets + 1 RGF House
Option 3:	Alt 1	Least Cost	**Least Cost = preferred option**
Option 4:	Alt 2	Alternative Option 1	Actiflo + New RGF's [Concrete]
Option 5:	Alt 3	Alternative Option 2	**Actiflo + Additional RGF's [steel]**
Option 6:	Alt 4	Alternative Option 3	Ceramic Membrane Plant
Option 7:	Alt 5	Alternative Option 4	Submerged Membrane Plant

Do Nothing, Option 1

This work is subject to a DWI section 28(4) Notice, therefore doing nothing is not considered a viable option.

In October 2020, a DWI notice was applied to the site requiring that changes be made to the process to install a validated UV irradiation system for the inactivation of Cryptosporidium oocysts (delivery AMP7, optimise the clarification process, upgrade the RGF process, and upgrade the wastewater treatment plant.

Preferred, Best Value, Option 2

Upgrading the existing works and constructing additional RGFs.

The current process at Egham WTW requires several changes to the site to meet DWI requirements and aid better control of *Cryptosporidium* removal on site. Therefore, the work required is as follows:

- Retrofitting an extension to FBC inlet channel to increase launder height to prevent overflow.
- Retrofitting lamella plates settlers into the FBCs to improve throughput and clarification.
- Build an additional RGF filter house (RGF 6), with four RGFs is required.
- Refurbishment of filter house 5 to include combined air and water scour.
- Upgrading GAC capacity by converting the current GAC wash water storage into 2 GAC contactors with UV reactors installed at each outlet.
- Install a new GAC wash water tank
- An additional balance tank, thickener and centrifuge

Least Cost Option

The least cost option is the preferred option: Upgrading the existing works and constructing additional steel RGFs.

Alternative Options

Replacing the FBCs with Actiflo and constructing additional RGFs in concrete [Option 4] or steel [Option 5].

Within this option, the clarification and filtration treatment processes for the first stream, ozonation and the disinfection treatment processes remain unchanged. The capacity of the GACs, along with UV, will require upgrade to sufficiently treat flows of 140 MLD and remove risk of *Cryptosporidium*. This can be achieved by the conversion of the existing GAC wash water tanks into two GAC contactors with UV reactors installed at each outlet. To optimise the clarification process, aid better solids removal and improve final water quality in line with DWI requirements, it is proposed that two AC10 Actiflo plants can be constructed offline to replace the existing hydraulically restricted FBCs.

The RGFs in houses 4 and 5 would not be able to cope with the changes in water quality given in the design envelope, and four additional RGFs are required. The additional filter house will constructed in line with houses 4 and 5 and share the same backwash facilities.

The existing capacity of the onsite sludge balancing tank is insufficient. A larger balancing tank will aid as a buffer between the waste streams and the waste treatment process.

An additional sludge thickener required.

Through process modelling the existing capacity of the centrifuges was identified to be insufficient if one centrifuge is taken out of service. Therefore, a third centrifuge will be required to provide sufficient standby capacity.

Alternative Option

Ceramic membranes [option 6]

Replacing FBCs and RGFs in houses 4 and 5 with ceramic membranes.

This option would replace both the clarification and filtration processes for the second process stream with a ceramic membrane plant. This option satisfies a major project driver and DWI requirement by preventing *Cryptosporidium* risk, as ceramic membranes pose as complete barrier to this contaminant.

Alternative Option

Submerged membranes [Option 7]

Submerged membranes offer a single stage treatment which can meet the DWI requirements applied to Egham WTW and provide an absolute barrier to Cryptosporidium. This scheme would involve a large, submerged membrane plant being installed on site. The submerged membrane plant would partially replace the existing clarification and filtration processes, by replacing the FBCs and RGFs in houses 4 and 5.

Option comparison

Qualitative analysis of the options considered efficacy, technological maturity, buildability, operability and maintenance, carbon efficiency, resilience, energy and consumables, and fit with future development of the site.

The following section details the quantitative cost analysis.

Option Assessment Approach

Economic Assessment

All five of the options were analysed, for capex, annual and 30 year opex, whole life cost, as well as NPV over 30 years.

Cost Estimation

Stantec engaged the services of Aqua Consultants, commercial engineering consultants with particular experience of the water industry, to produce cost and carbon estimates. Aqua hold a mature and extensive database of estimating material. Cost estimates have been prepared using a combination of cost models and unit costs based on experience within the Water Industry, through AMP7 and AMP6, PR19 and PR24 as well as budget estimates from the market.

The level of detail is developed to sub-process and key asset level, but is yet to progress to outline design stage, hence confidence level is medium.

Benefit Estimation

By meeting the DWI notice requirements by 2027, the preferred option will deliver the benefits of enhanced treatment, protecting customers from the health risk posed by cryptosporidium, and ensuring that a site output of 140Mld is reliably attainable through all raw water quality conditions. The benefits to customers have been applied conservatively from 2030 and sensitivity analysis carried out as described below.

Efficiency

The DWI notice requires significant process changes, increasing the capacity, efficacy, and lifespan of existing assets, and adding RGF units to improve treatment further is a very cost effective and environmentally sound option. The economic assessment section gives further detail on the comparison between options.

Assumptions Made

AQUA consulting has assumed outputs for all options based on a 20 year design life for the mechanical and electrical assets.

The designs from the suppliers assume a constant flowrate of the desired 140 MLD from the process, as opposed to a set max, average and min flow. The process models are also based on this max flow.

Existing back wash system for RGF 4 and 5 is sufficient for the additional RGFs. Whilst the FBCs are taken offline, it is assumed the site will be able to sustain adequate flows through the sedimentation plant and supplemented by flows from Chertsey and Walton WTWs

The maximum values of the raw water quality sampling data have been used in the design of the various options for a constant flow of 140 MLD.

Uncertainties and Sensitivity Analysis

We have used the Ofwat and WINEP valuations and have focused our attention on the metrics and the benefit profiles.

We have made conservative estimates for when benefits will start and finish, and how they increase and decrease over time. As such, our economic analysis is inherently conservative by nature. We then consider the benefit metric for sensitivity studies as this becomes the most material uncertainty in the analysis.

Within our spreadsheet we use the goal seek function to determine the value of a metric of concern that would be required to make the scheme cost beneficial. This provides a sensitivity check on the metric and enables commentary on the reasonableness of the economic analysis. We have run sensitivity checks on all significant benefit metrics.

Third Party Assurance and Audit Trail

The study was carried out by our professional service suppliers Stantec, and their contractor Aqua, providing 3rd party assurance. Progress meetings and report and cost reviews were periodically undertaken by Affinity Water internal stakeholders and project team.

Option Assessment

Commentary on the Economic Assessment

All five of the options were analysed, for capex, whole life cost, as well as NPV for capex and opex over 30 years. Each option was assessed as achieving the same level of customer benefits.

Option Definition			
Option 1:	Baseline	Baseline (Do nothing or maintain)	Baseline/Existing/Do Nothing
Option 2:	Core	Preferred Option	Existing Assets + 1 RGF House
Option 3:	Alt 1	Least Cost	Least Cost = preferred option
Option 4:	Alt 2	Alternative Option 1	Actiflo + New RGF's [Concrete]
Option 5:	Alt 3	Alternative Option 2	Actiflo + Additional RGF's
Option 6:	Alt 4	Alternative Option 3	Ceramic Membrane Plant
Option 7:	Alt 5	Alternative Option 4	Submerged Membrane Plant

Options	Total Investment	5 yr Investment	Total NPV	NPV Costs (Capex)	NPV Costs (Opex)	Total NPV Benefits	Cost Beneficial	Benefit / Cost
Option 1:	£ -	£ -	£ -	£ -	£ -	£ -	Yes	0.00
Option 2:	£ 39,910,234	£ 14,061,731	£ 40,869,705	-£ 12,330,516	-£ 6,396,751	£ 59,596,973	Yes	3.18
Option 3:	£ 39,910,234	£ 14,061,731	£ 40,869,705	-£ 12,330,516	-£ 6,396,751	£ 59,596,973	Yes	3.18
Option 4:	£ 161,072,300	£ 42,658,146	-£ 8,970,255	-£ 36,544,973	-£ 32,022,255	£ 59,596,973	No	0.87
Option 5:	£ 141,174,093	£ 32,124,296	£ 1,667,817	-£ 26,634,958	-£ 31,294,198	£ 59,596,973	Yes	1.03
Option 6:	£ 246,319,356	£ 49,421,461	-£ 29,185,552	-£ 48,161,083	-£ 40,621,442	£ 59,596,973	No	0.67
Option 7:	£ 190,826,583	£ 37,575,383	-£ 9,748,248	-£ 35,814,515	-£ 33,530,706	£ 59,596,973	No	0.86
Option 8:	£ -	£ -	£ -	£ -	£ -	£ -	Yes	0.00
Option 9:	£ -	£ -	£ -	£ -	£ -	£ -	Yes	0.00
Option 10:	£ 37,024,225	£ 11,175,721	£ -	-£ 9,842,848	-£ 6,396,751	£ 16,239,599	Yes	1.00

The sensitivity analysis was carried out by applying a reduction factor that achieved a benefit/cost ratio of 1 [Option 10 above].

Preferred, Best Value, Option

The preferred option 'Existing assets + 1 RGF house' is also the lowest cost option. The tables above illustrate it has the lowest capital investment, the best 30 year NPV, and the best benefit/cost ratio. Sensitivity analysis shows that even with a reduction to only 8.5% of expected benefits the project will remain cost beneficial.

The RGFs would be of a steel construction, reducing the cost and expected lifespan of the process, achieving the benefit of maximising the utilisation of the site's remaining assets and allowing for future developments in AMP10 when other solutions may be more appropriate. It is estimated that the lifespan of a steel construction RGF house would be similar to the remaining lifespan of the current

RGFs. This time allows for extensive pilot plant work on the membrane solutions, which will confirm the most effective design in terms of construction, operation, and power requirements. It will also give an opportunity for other technologies to emerge which can also be considered during this timeframe.

Least Cost Option

The least cost option is the same as the preferred option above.

Alternative Option 1

Actiflo and new concrete RGFs

All options achieved the same assessed customer benefits, so the differentiation was determined by the financial analysis, carbon assessment, and the fit with the long term delivery strategy. This option was deemed not cost beneficial due to being high capital costs and an inferior benefit/cost ratio. Furthermore investing in completely new concrete RGF's would commit to an extended asset life for these new assets that would be out of kilter with the remaining asset life of many other site assets.

Alternative Option 2

Actiflo and additional steel RGFs

All options achieved the same assessed customer benefits, so the differentiation was determined by the financial analysis and then the fit with the long term delivery strategy. This option could be considered the second most cost beneficial due to a benefit/cost ratio above one. The key difference between this and building all new concrete RGF's is that the additional RGF's would be cheaper and the relatively lower asset life more consistent with the life expectancy of the rest of the site assets.

The financial analysis however clearly makes this a less attractive option than the preferred option.

Alternative options 3 and 4

The ceramic and submerged membrane options were least favourable financially due to high investment costs, and lowest benefit/cost ratios. Whilst they would enable replacement of other treatment stages such as clarification and RGF, this does not make a favourable economic argument as those assets still have significant life expectancy. The performance of those existing assets can be improved to meet the requirements of the DWI notice.

Meeting Affinity Water's Outcomes

To facilitate an effective and efficient process to look at the implications of the PR24 Business Cases on carbon (operational and embedded), biodiversity, including Biodiversity Net Gain and Natural Capital all Business cases were screened with relevant Business case leads to ascertain where there was potential for material impact on Carbon, Biodiversity or Natural Capital. Once the potential for an impact was identified the significance associated with that impact was explored with relevant specialists and business case leads.

Surgery sessions were held with business case leads to set out considerations for each of the three assessment areas. Criteria to assess significance of carbon impact included:

- A material increase or decrease in operational CO2 emissions and/or
- An impact on capital carbon, e.g. identification of requirement for a physical build or change in capital maintenance resource use

Both the embedded carbon (resulting from construction activities) and operational carbon (resulting from energy and chemical use) were assessed

Stantec analysed the carbon costs for each option using their carbon tool, shown in the table below.

Option	Embodied Carbon Emissions (tCO_2e) – *from construction*	Annual Operational Carbon Emissions (tCO_2e/yr)	Cumulative (Whole Life) Carbon Emissions (tCO_2e)
0 – Baseline (Do Nothing)	0	12,678	473,763
Option 3.1b – Actiflo + Additional RGFs	3,033	15,442	645,558
Option 3.2b – Actiflo + New RGFs	3,372	15,815	690,485
3.3 – Ceramic Membrane	1,005	12,563	495,735
3.4 Submerged Membrane	N/A	N/A	N/A
3.5 – Upgrade of the existing assets	2,222	13,450	522,532

Ceramic membranes were shown to be the lowest whole life carbon impact, however that option was ruled out for the reasons explained in the previous section, and detailed energy costs were not known at this stage. Also for the ceramic membrane option, the carbon assessment did not include for the removal of assets made obsolete before their predicted end of life.

Of the remaining options, using the existing assets alongside the new RGFs was considerably lower than the alternatives, with the option of construction material being the minor difference in whole life cumulative carbon. For RGF options the steel structures have been assumed to use 30% of the volume of concrete structure.

Justification of the Preferred Option

The preferred option 'Existing assets + 1 RGF house' is also the lowest cost option. The tables above illustrate it has the lowest capital investment, the best 30 year NPV, and the best benefit/cost ratio. It also serves as the best fit considering the existing asset remaining life, and future development potential from AMP10 onwards.

The sensitivity analysis indicates the project remains cost beneficial at just 8.5% of the expected benefit to site output, a wide margin that gives high confidence the investment will deliver the customer benefits.

Delivery Considerations

Related Projects

The project is related to the Regulation notice also issued with regard to Iver WTW and similar cryptosporidium risk regarding that plant.

Lessons Learnt

Lessons from similar civil infrastructure installations, such as the construction of additional GAC capacity at Iver in 2018, will be reviewed to inform the delivery process. Ongoing UV installations at both Iver and Egham will also provide beneficial information relating to power supplies and hydraulic calculations.

Delivery Risk Management

In December 2024 we will submit our final option for Egham Water Treatment Works for the listed deliverables as per the section 28 notice. At this stage we will need to commence detailed design and build of the solution to meet the 2027 completion date. To ensure constructability and appropriate construction budgeting is taking place we are engaging with our larger construction partner Galliford Try in early contractor involvement (ECI) to ensure the design is both deliverable and affordable. A dedicated programme team is being designed to deliver the Iver/Egham schemes and other surface works treatment schemes. This will focus the attention on delivery of these key projects.

Egham is very spatially constrained and careful consideration will be needed in exploring options for utilising existing infrastructure or removing assets to procure land space for new developments. The major delivery risk is the integration of the additional filters to the RGFs in a very limited space. Thorough planning and design will be require to mitigate issues within the build. The use of 4D/5D design may support what could be a complicated build process whilst keeping the site operational.

Modifications of existing treatment will require multiple process outages limiting the output from the site and the dedicated programme team will plan these appropriately to ensure successful delivery.

Planning permission is not considered a significant risk due to the current site layout, but will still need to be agreed and the appropriate pre-application process followed to ensure issues are mitigated early.

Process modelling results have shown that the thickener hydraulic loading rate is near to maximum, and options to manage this include employing volute technology which will be considered in the detailed design. This would have the advantage of offering combined thickening and dewatering in one unit, overcoming the capacity and available space constraint.

Other design elements such as head loss and pipe sizes, scada and PLC capacity will be incorporated into the detailed design.

Further detail regarding how we have ensured the deliverability of our full investment portfolio is provided within AFW 32 Deliverability of our Plans.

Monitoring and Reporting of Benefits

The project must be delivered in line with the DWI notice date of Dec 2027, and will be achieved by delivery through project gateways and milestones. The DWI under the statutory notice require us to report at different stages to ensure that we are on track with delivering the intended outputs as laid out.

Affinity Water

Raw Water Deterioration Programme

PFAS Affected Sites

July 2023

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Summary

PFAS (Perfluoroalkyl and Polyfluoroalkyl Substances) are compounds found in fire-fighting foams and anti-staining coatings for carpets and textiles, among other uses. There are multiple PFAS compounds present in some of the groundwater aquifers from which we abstract water for supply to customers. This is usually the result of diffuse or point-source pollution events which took place in the past, although may also be related to ongoing activities.

Toxicity data is not available for many PFAS, however some PFAS, such as perfluorooctanoic acid (PFOA) and perfluorooctane sulfonic acid (PFOS) (two specific compounds included within the PFAS group), have been associated with adverse effects in animal and human studies at sufficient levels of exposure.

In January 2021 DWI (Drinking water Inspectorate) published revised guidance for the parameters PFAS and PFOA. This guidance reduced the value for wholesomeness (effectively the PCV) for PFOS from 1 µg/l to 0.1 µg/l and for PFOA from 5 µg/l to 0.1 µg/l. In July 2022 the wholesomeness value was extended to 45 other PFAS (IL 03/22).

Following the DWI wholesomeness limit changes, we reviewed our risk assessments across all sources and drinking water supplies and identified four water treatment sites (WTWs) as requiring investigation: Baldock Road and Bowring in combination, Blackford, Holywell and Wheathampstead. Following optioneering and economic impact assessment, we recommend the following for investment and inclusion in the PR24 portfolio:

- Replacement of the media in, and recommissioning of, the GAC contactors at Holywell
- GAC contactors at Bowring to treat all water from Baldock Road and Bowring sources (in combination with enhanced blending)
- GAC contactors at Blackford WTW [***note this is additional to turbidity and manganese removal treatment in the WINEP Business Case***]; and
- Management of the risk at Wheathampstead without additional capital investment in a new treatment process in this AMP, while continuing to ensure adequate blending of the water at Shakespeare Road, and implementation of a research and development trial into the effectiveness of a PFAS-specific ion exchange resin.

The requirement for this investment is to meet the commitments set out in our Strategic Direction Statement to "Deliver what our customers need, ensuring affordability for all," which encompasses "Exceed[ing] customers' expectations for drinking water," and to "Be prepared for change and resilient to shocks and stresses".

Project Details

AMP8 Spend	2025-26	2026-27	2027-28	2028-29	2029-30	Total
Capex (£m)	1.12	4.59	6.34	5.70	0.00	**17.74**
Opex (£m)	0.19	0.19	0.33	0.39	0.52	**1.63**
Totex (£m)	1.31	4.78	6.67	6.08	0.52	**19.37**
Drivers						
100%	Addressing raw water quality deterioration (grey solutions)					
Benefits						
Loss of Production Capacity (Ml/d) Capex and Opex Savings (£m)						
Economic Analysis						
NPV Costs (£m) (2025-55)		**23.8**	NPV Benefits (£m) (2025-55)			**43.8**
NPV (£m) (2025-55)		**20.0**	Benefit / Cost Ratio			**1.8**

Six Capitals

Natural	Social	Financial	Manufact.	Human	Intellectual
	★ ★ ★	★	★ ★		

Project Description

This business case is driven by a statutory duty to maintain potable water quality in the context of deteriorating raw water quality conditions and a change in the wholesomeness threshold limit as defined by the DWI. The investment will result in a step-change in the service level provided to consumers and is therefore Enhancement expenditure.

In the business case we describe a series of projects which will address high PFAS concentrations detected at our four high risk sites (Tier 3 sites). These projects include upgrading and installing new treatment, as well as being adaptable, and incorporate a level of research and development to ensure our strategies can respond to potential future changes in regulation, such as an increased range of PFAS chemicals to detect and tighter thresholds.

At **Holywell WTW** we will change the media in the existing 12 GAC contactors for virgin media, especially selected for its capability to remove PFAS compounds. Some additional software modifications will be made at site to enable more stable influent concentration of PFAS compounds to the new GAC treatment. Note that 6 contactors are planned for media exchange in AMP7, and this business case includes the costs for the remaining 6 in year 1 of AMP8.

At **Blackford WTW** we propose installing new GAC contactors to remove the PFOA present in the raw water. Note this is additional to turbidity and manganese removal treatment in the WINEP Business Case and delivery will be considered holistically.

At **Baldock Road & Bowring WTW** we propose enhancing the blending controls at the beginning of AMP8 and installing new GAC contactors at Bowring WTW to remove the PFAS present in the raw water abstracted at both Baldock Road and Bowring WTW at the end of AMP8. While this is the preferred and best value option at this time, we will draw on our own experiences with implementing PFAS treatment at Blackford and Wheathampstead. We have investigated the potential for GAC at Baldock Rd only, however this was assessed not to be a viable option because of the elevated concentrations of solvents (sum of tri- and tetra-chloroethene) and the impact on GAC if it is before the air stripper stage.

At **Wheathampstead WTW** we propose to continue monitoring the concentration of PFAS compounds in the raw and treated water at Wheathampstead WTW, to establish a baseline for how much can be removed by the ion exchange plant currently under construction in AMP7 for hexavalent chromium (Cr VI) removal. It may be necessary to make additional investments at Wheathampstead WTW in the future, for example changing the resin used in the ion exchange process to one more suited for removal of PFAS compounds. Therefore, we also propose to undertake research and development of PFAS specific ion exchange resin during AMP8.

Project Development

Baseline Assessment

1. PFAS

As a result of their widespread use and persistence, PFAS are being found to be present in many different environments. Toxicity data is not available for many PFAS, however some PFAS, such as PFOA and PFOS, have been associated with adverse effects in animal and human studies at sufficient levels of exposure[1]. This has led to the restricted use of some of these substances in a variety of global markets.

Under section 68 of the Water Industry Act 1991 water companies have a statutory duty to supply wholesome water. Water supplies provided for human consumption (which includes cooking, drinking, food preparation and washing) and to premises where it is used for food production must meet the wholesomeness requirements of these Regulations. The Water Supply (Water Quality) Regulations 2016 regulation 4, states that water is deemed to be wholesome if it contains concentrations or values in respect of various properties, elements, organisms and substances that do not contravene the prescribed maximum, and in some cases, prescribed minimum, concentrations or value (PCV) and must not contain any micro-organism, parasite or substances at a level which could be a potential danger to human health, including where no standard has been set.

In the absence of a statutory standards for PFAS in drinking water England and Wales, the DWI have developed an approach and produced tiered guideline values[2] for water companies to adhere to. The first edition of the guidance issued in May 2007 set wholesomeness thresholds at 1.0 µg/l for PFOS and 10 µg/l for PFOA, which was revised again in October 2009 to reduce the wholesomeness threshold for PFOA to 5.0 µg/l.

In January 2021 the drinking water wholesomeness thresholds for PFOS and PFOA were both reduced again to 0.1 µg/l. This guidance from DWI was updated in July 2022 extending the guideline value of 0.1 µg/l to 45 other PFAS (IL 03/22)[3]. DWI considers that the guidance limit of 0.1 µg/l for these PFAS compounds is robust with an appropriate margin of safety to ensure the wholesomeness of drinking water.

In parallel with DWI's review of these chemicals, the European Union (EU) proposed a revision of the Drinking Water Direction (DWD[4]), the final version of which was adopted in December 2020. The revised DWD included PFAS for the first time and set an even more stringent parametric value of 0.1 µg/l for the sum of 20 named PFAS, and 0.5 µg/l for total PFAS. Article 25 of the DWD outline a transitional period for Member States to take the measures necessary to ensure that water intended for

[1] DWI PFAS and Forever Chemicals
[2] Guidance on the Water Supply (Water Quality) Regulations 20161 specific to PFOS (perfluorooctane sulphonate) and PFOA (perfluorooctanoic acid) concentrations in drinking water.
[3] IL_03-2022_PFAS_Guidance.pdf
[4] Drinking Water Direction

human consumption complies with the parametric values set out in Part B of Annex I for PFAS Total and Sum of PFAS by 12 January 2026. Table 1 below shows an explanation of the EU 'sum of 20 named PFAS' and 'total PFAS'.

Table 1. EU 'sum of 20 named PFAS' and 'total PFAS'

Parameter	Parametric value	Unit	Notes
PFAS Total	0,50	μg/l	'PFAS Total' means the totality of per- and polyfluoroalkyl substances.
			This parametric value shall only apply once technical guidelines for monitoring this parameter are developed in accordance with Article 13(7). Member States may then decide to use either one or both of the parameters 'PFAS Total' or 'Sum of PFAS'.
Sum of PFAS	0,10	μg/l	'Sum of PFAS' means the sum of per- and polyfluoroalkyl substances considered a concern as regards water intended for human consumption listed in point 3 of Part B of Annex III. This is a subset of 'PFAS Total' substances that contain a perfluoroalkyl moiety with three or more carbons (i.e. –CnF2n–, n ≥ 3) or a perfluoroalkylether moiety with two or more carbons (i.e. –CnF2nOCmF2m–, n and m ≥ 1).

In the context of the UK water industry, Affinity Water is facing a more significant challenge from PFAS compounds than any other water company by a significant margin, as shown in data released in the 2022 DWI Chief Inspector's report[5]. The full data tables are presented in the supporting information section (Figure 22 and Figure 23).

As part of our investigation into the impact on local groundwaters of the fire-fighting foams used at Buncefield following the explosion at the fuel depot in 2005, our laboratory developed an analytical method for the detection of PFOS and PFOA in water at concentrations in the nanogram per litre range in 2006. We started our monitoring programme at the sources located around the Buncefield area and then expanded it to all our sources. Consequently, we have a good understanding of PFAS concentrations in our source water and drinking water supplies.

Prior to 2021, the drinking water wholesomeness thresholds for PFOS and PFOA were 1.0 and 5.0 μg/l, respectively. As all the results from our source monitoring had been less than 0.4 μg/l, up until the end of 2020 our assessment of the risk from PFOS/PFOA was that it was low and manageable across all our source waters.

The significant reduction in the wholesomeness thresholds at the start of 2021 led us to revaluate our risk assessments. For many of our sources we have found that concentrations for PFAS are below 0.05 μg/l (i.e. 50 % of the wholesomeness threshold) and continue to regard the risk at these sites as low and manageable. However, several sources show elevated PFAS concentrations above 0.1 μg/l (the wholesomeness threshold) and on an increasing projection.

[5] DWI Chief Inspector's report 2022

Our laboratory has continued to develop in-house analytical methods for a wider range PFAS. In February 2022, our laboratory successfully completed the work on increasing the number of compounds detected in our PFAS analysis to include all 45 PFAS listed in the updated DWI guidance letter of July 2022 (IL 03/22). The laboratory team has started the validation process for the PFAS compounds used in the EU "Sum of PFAS" calculation (a subset of 20 of the listed PFAS compounds) and they expect to complete this by the end of 2022. They will then start the validation process for the remaining 27 PFAS compounds and expect to complete this in 2023.

Data Analysis

As part of our data analysis into the impact PFAS compounds in our source waters and drinking water supplies the following assessment was completed:

- Reviewed our DWSP to identify where the residual risk (likelihood x consequence) is >10 for PFOS and PFOA compounds (i.e. possible within next five years).
- Reviewed PFOS and PFOA sample results January 2010 to April 2022.
- Reviewed the sample results of the additional PFAS compounds (both the EU20 "Sum 20 PFAS compounds" and the "Sum 47 compounds") taken since 2021. This showed 8 additional PFAS compounds had been detected (7 of which were EU 20 compounds) in 28 sample points.
- Cross checked our March 2022 assessment of sampling data against the DWI tier thresholds, this had placed 58 sources in Tier 2 (>0.01 µg/l) and 3 sources in Tier 3 (>0.1 µg/l).
- Cross checked Catchment Management top 20 abstraction sites showing high risk for organic compounds.
- Mean and maximum values were calculated from the sample results of all sources for the following parameters: PFOS, PFOA, "EU 20 sum" and total PFAS.
- 14 water supply systems (WSS) were identified as showing PFAS compound sample results above 0.05 µg/l (i.e. >50% wholesomeness threshold).
- Further interrogation of the 14 supply systems, looked at whether the trend was increasing, stable or decreasing, the influence of groundwater levels, as well as eliminating sample result anomalies.
- Four WSS were identified as priority to be taken forward for optioneering and solution development.

2. Baldock Road Sources

The Baldock Road sources are situated in an industrial area in Letchworth. The water from these sources contains elevated concentrations of tri and tetrachloroethene (industrial solvents), hexavalent chromium and the pesticide bromacil (see other contaminants below). The PFOS concentrations detected are above the wholesomeness threshold and on an increasing trend over the last decade as shown in the graph below (Figure 1). The concentration detected now continually exceeds 0.1 µg/l and are at Tier 3 level which is considered unwholesome.

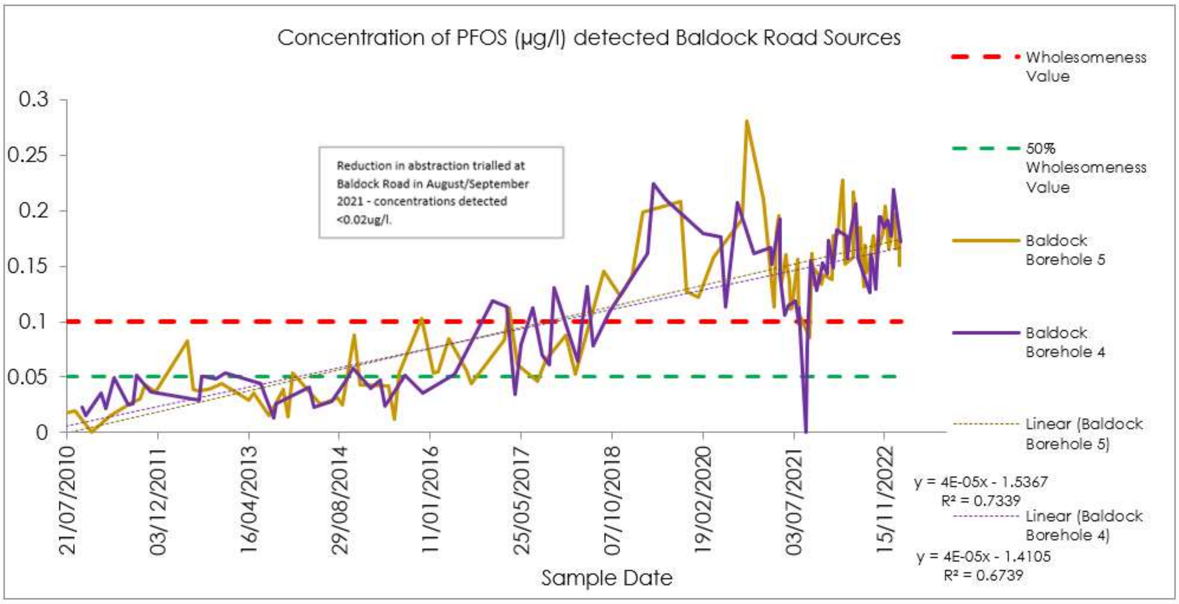

Figure 1. Concentration of PFOS (µg/l) detected at Baldock Road Sources

The Baldock Road sources are disinfected with Bowring source water at Bowring WTW and this water then blends with water from Fuller WTW before going into Weston Hills reservoir and onto supplying the Baldock/Letchworth area. This blending brings the concentration of PFOS down to below 0.1µg/l as shown by the graphs below (Figure 2 and Figure 3). Prior to the reduction in DWI's wholesomeness threshold we knew the concentrations in the drinking water supply would be well below the 1 µg/l so did not take many samples.

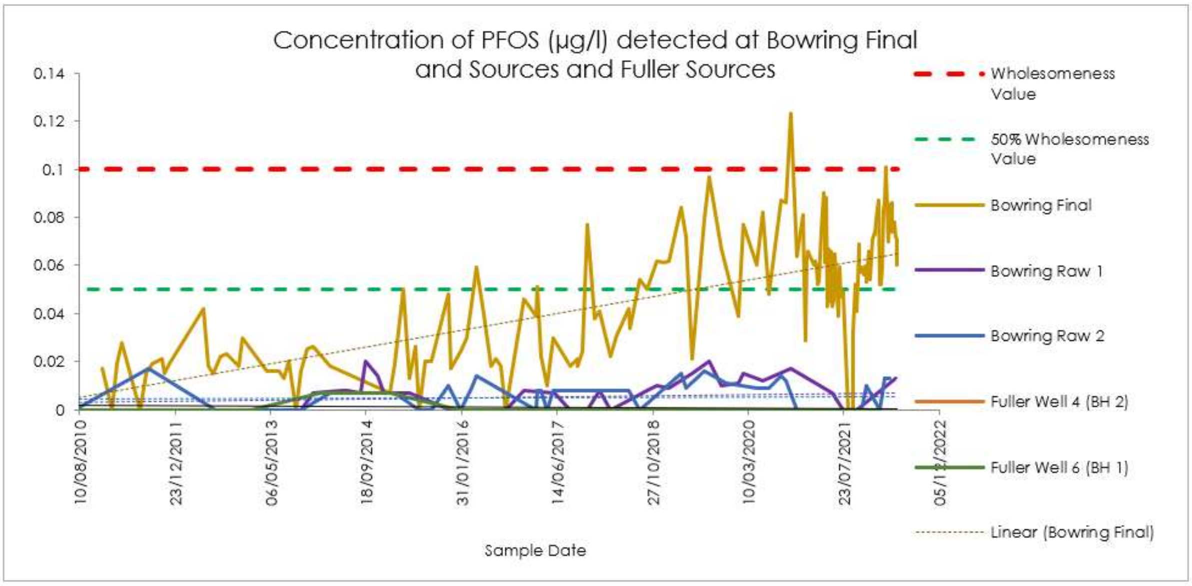

Figure 2. Concentration of PFOS (µg/l) detected at Bowring Final and Sources and Fuller Sources.

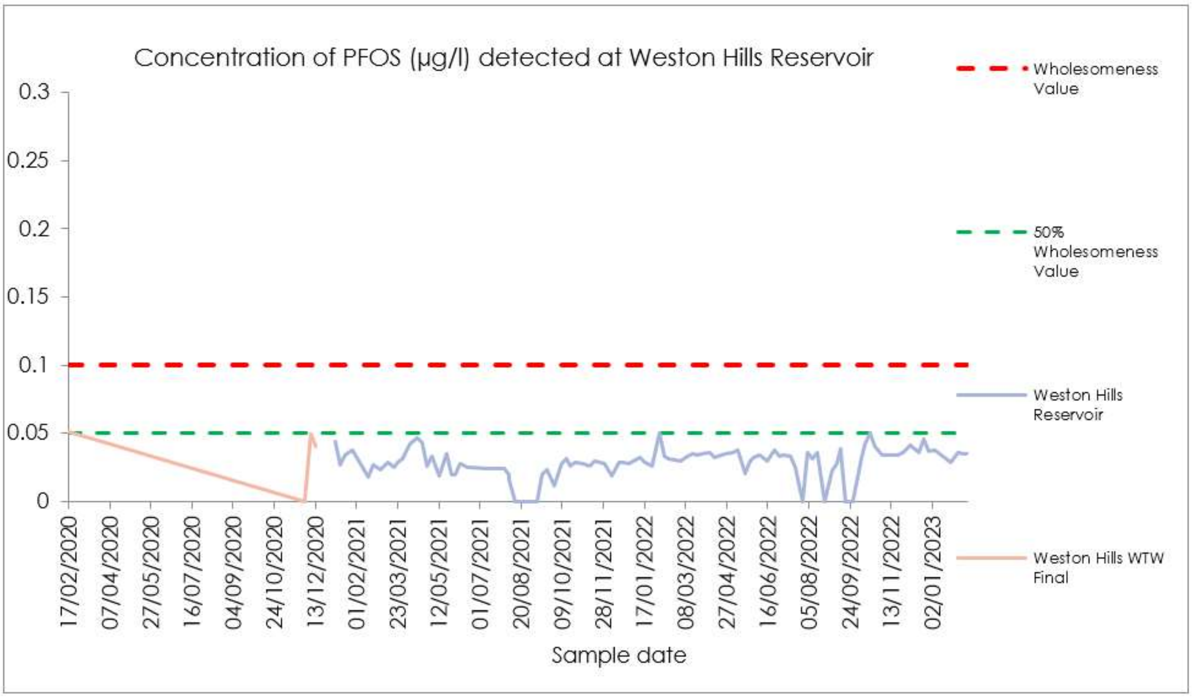

Figure 3. Concentration of PFOS (µg/l) detected at Weston Hills Reservoir.

There are various blend scenarios to manage the concentrations of both PFOS and Chromium VI. From Table 2 below you can see that PFOS concentrations are at the highest risk of exceeding the wholesomeness thresholds with the current blend controls.

Table 2. Blending Scenario Calculations:

Source	Average output (2016-2020)	Min. output	Max. output	Max. Cr VI	Max. PFOS	Max. PFOA
Baldock Road	3.26	2.718	3.783	14.9	0.281	0.015
Bowring	4.684	4.224	5.095	1.7	0.02	0
Fuller	5.095	4.313	5.78	0	0	0
Slip End	4.146	3.38	4.5	0	0	0
	Scenario	Chr VI	PFOS	PFOA		
Weston Hills	Average outputs, no Slip End to Weston	4.34	0.077	0.004		
Weston Hills	Average outputs, all Slip End to Weston	3.29	0.059	0.003		
Weston Hills	Maximum Baldock Road and Bowring, Minimum Fuller, no Slip End	4.93	0.088	0.004		
Weston Hills	Maximum Baldock Road and Bowring, No Fuller, no Slip End	7.32	0.131	0.006		
Weston Hills	Maximum Baldock Road and Bowring, No Fuller, all Slip End to Weston	5.30	0.095	0.005		

The supply from Baldock Road, Bowring WTW and Fuller WTW sources can also combine with flow from Slip End WTW as it enters Weston Hills reservoir. As this source also supports Wickerhall reservoir it is not included in the blend calculation (Table 3) below which shows the worst-case scenario should concentrations of PFOS reach 0.281 µg/l at Baldock Road.

Table 3. Worst-case scenario should concentrations of PFOS reach 0.281 µg/l.

Scenario	**PFOS Concentration at Weston Hills SR µg/l**
Average outputs at Baldock Rd, Bowring and Fuller WTW	0.076
Maximum outputs at Baldock Road and Minimum Bowring and Fuller WTW	0.088

Our forecast is that the average PFOS concentration in Baldock Road raw 4 and 5 will reach 0.25 µg/l by 2030 and the peak values (assuming a factor of 2.0) could already exceed the maximum concentration of 0.281 µg/l limit for the blending to be sufficiently mitigated to ensure concentrations in the water leaving Weston Hills reservoir remain below 0.1 µg/l.

Extended PFAS analysis shows the presence of other PFAS compounds with a concentration around 0.068 µg/l. We currently consider the total concentration of PFAS in the drinking water supply from Weston Hills reservoir would be less than 0.1 µg/l but with the concentration of PFOS showing an increasing trend it is likely that treatment would be required to maintain EU sum PFAS concentrations below 0.1 µg/l.

The graph and pie chart below (Figure 4 and Figure 5) show the extended PFAS compound profile seen in the samples taken from Bowring water supply system during 2022 to February 2023.

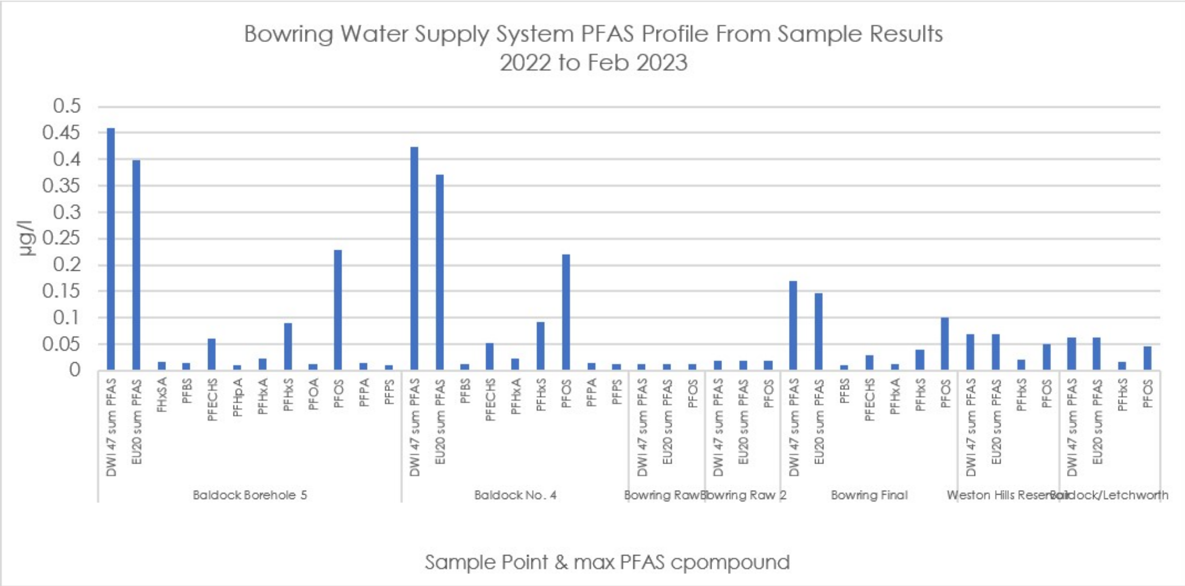

Figure 4. Bowring Water Supply System PFAS Profile 2022 to Feb 2023.

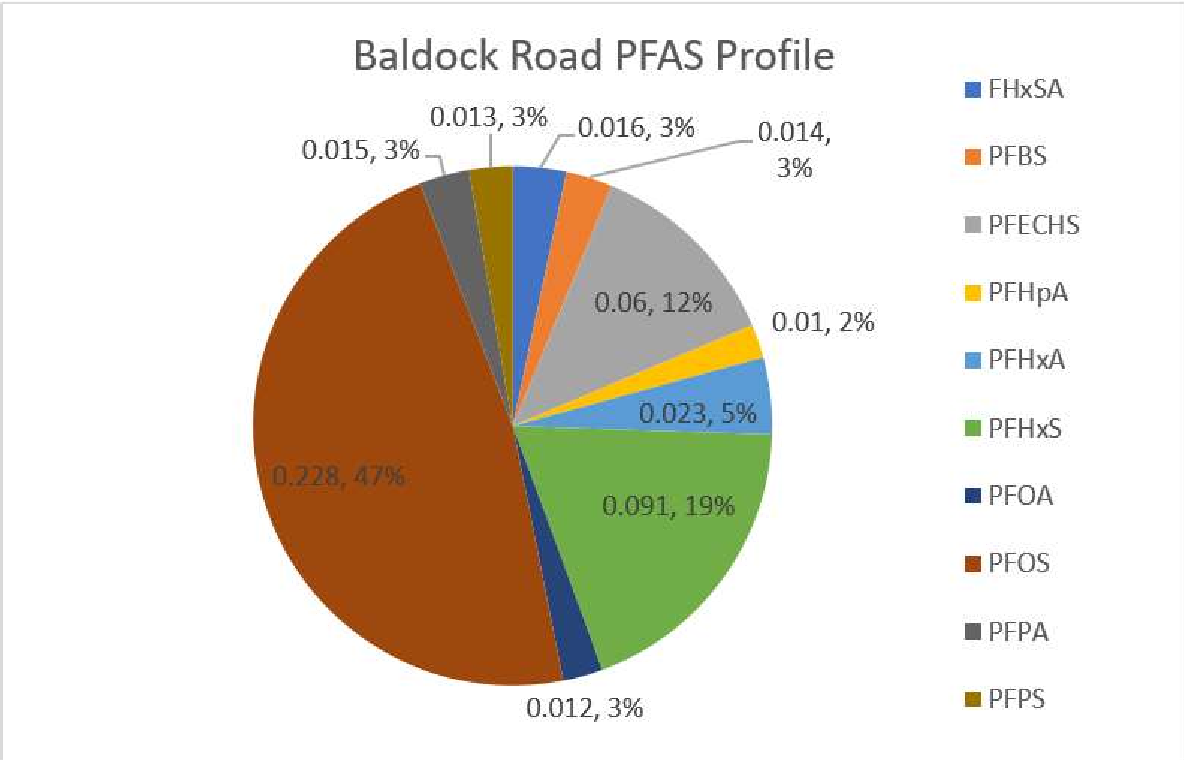

Figure 5. Baldock Road PFAS Compound Profile.

Other contaminants at Baldock Road Sources:

Chromium concentrations are also on an increasing trend, current blending controls primarily for PFAS concentration mitigation, brings the concentration down in the final water to below 50% of the wholesomeness value as shown by the graph below (Figure 6).

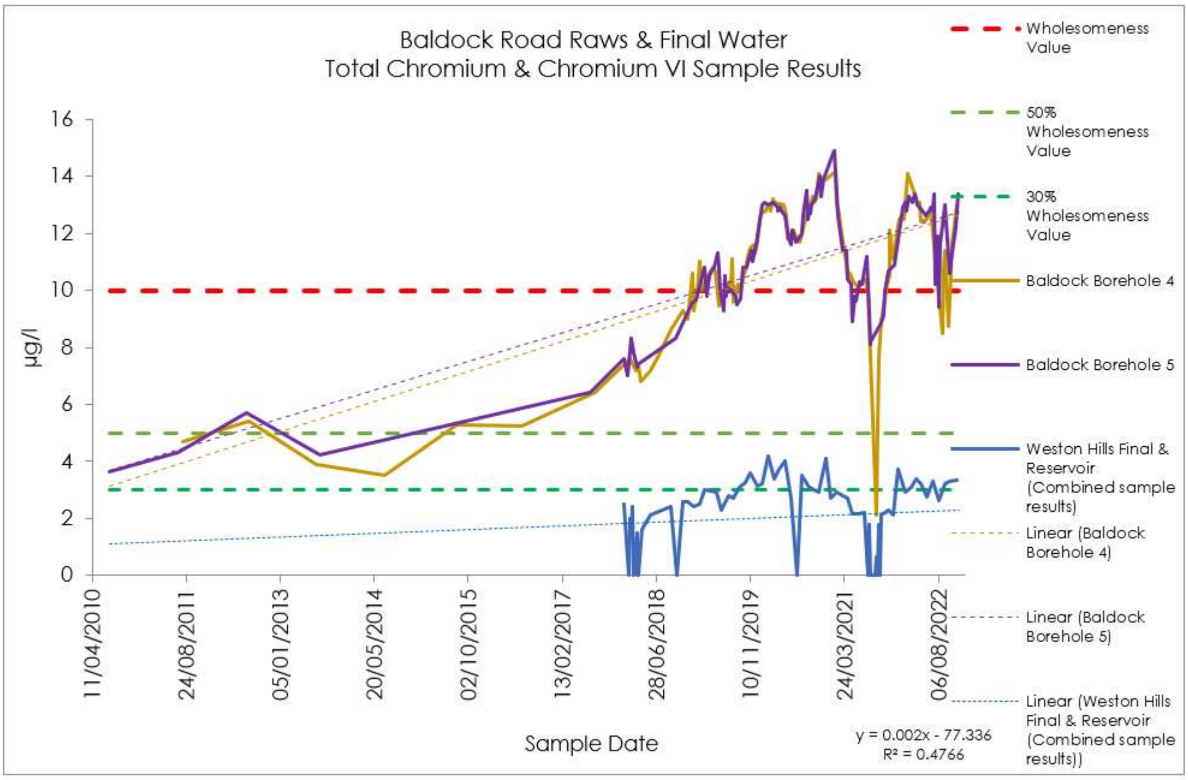

Figure 6. Baldock Road Sources and Final Water Total Chromium and Chromium VI Sample Results.

Bromacil concentrations at Baldock Road and Bowring sources are elevated (average results of 0.43 µg/l and 0.28 µg/l respectively). Trends are relatively stable, with a slightly declining trend seen at Bowring Final (average result of 0.23 µg/l) as shown in the graph below (Figure 7). The concentrations are below the PCV (0.1 µg/l) in the final water at Weston Hills (average result of 0.01 µg/l), as shown in the second graph below (Figure 8). We believe the reduction in Bromacil is through the existing disinfection treatment processes of UV/ chlorination and no additional treatment is needed.

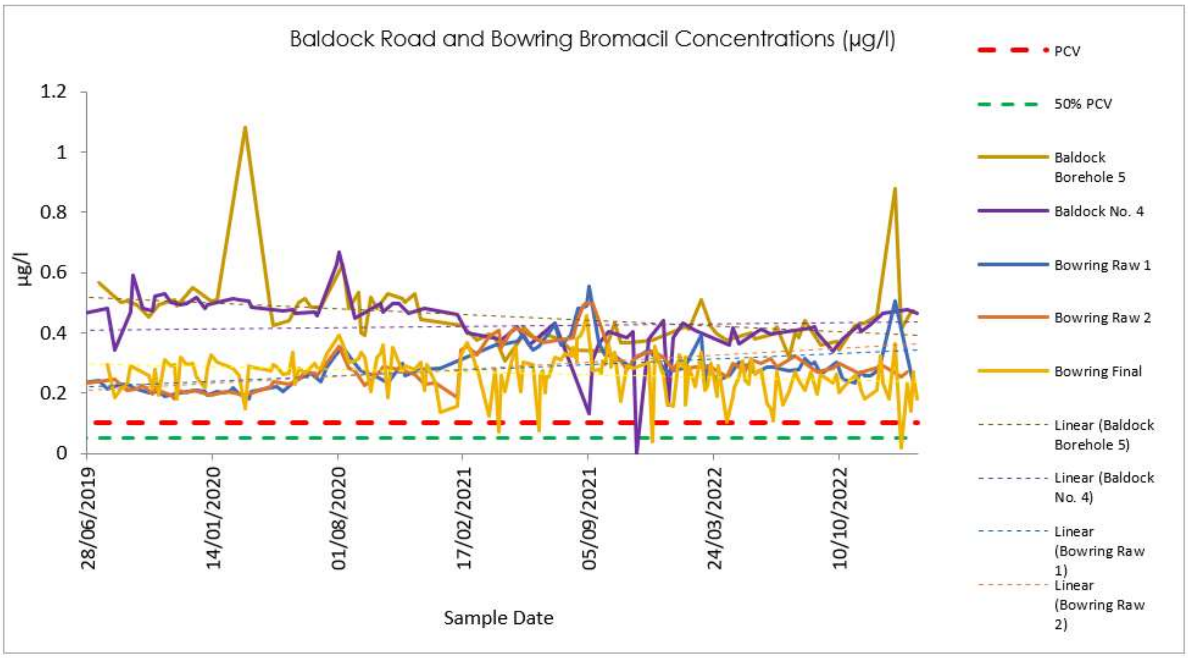

Figure 7. Baldock Road and Bowring Bromacil Concentrations (µg/l).

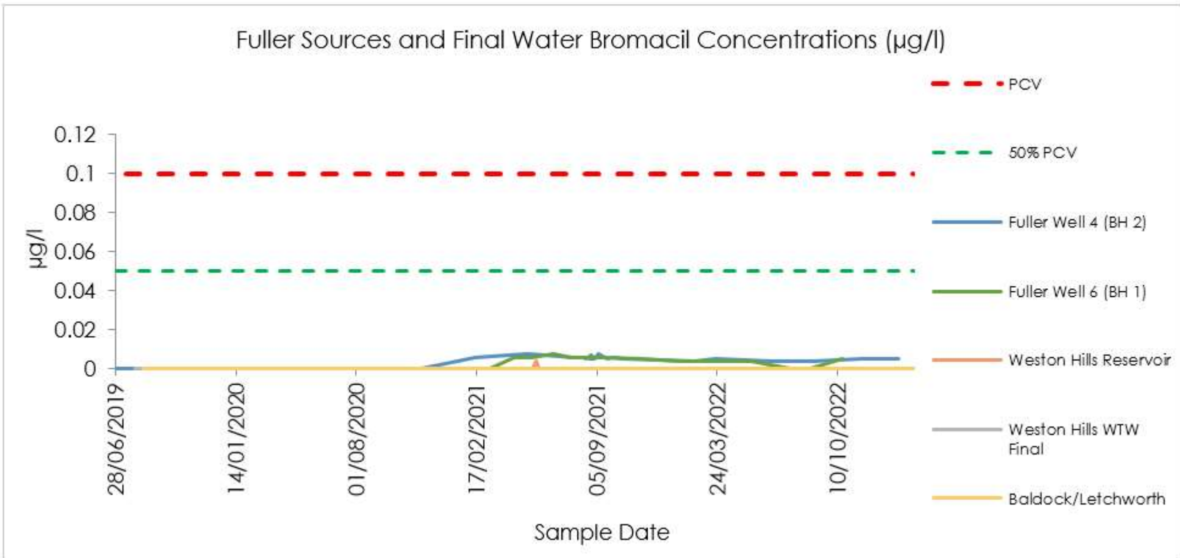

Figure 8. Fuller Sources and Final Water Bromacil Concentrations (µg/l).

Sum of tri- and tetra-chloroethene (TCE) concentrations at Baldock Road and Bowring sources are elevated (average results of 45 µg/l and 6.5 µg/l respectively), and trends are declining (Figure 9). The combined raw water is passed through an air stripping tower to reduce the concentrations, concentrations at Bowring Final have an average result of 0.5 µg/l and are below the PCV (10 µg/l). Concentrations in the final water at Weston Hills average 0.2 µg/l, as shown in the second graph below (Figure 10).

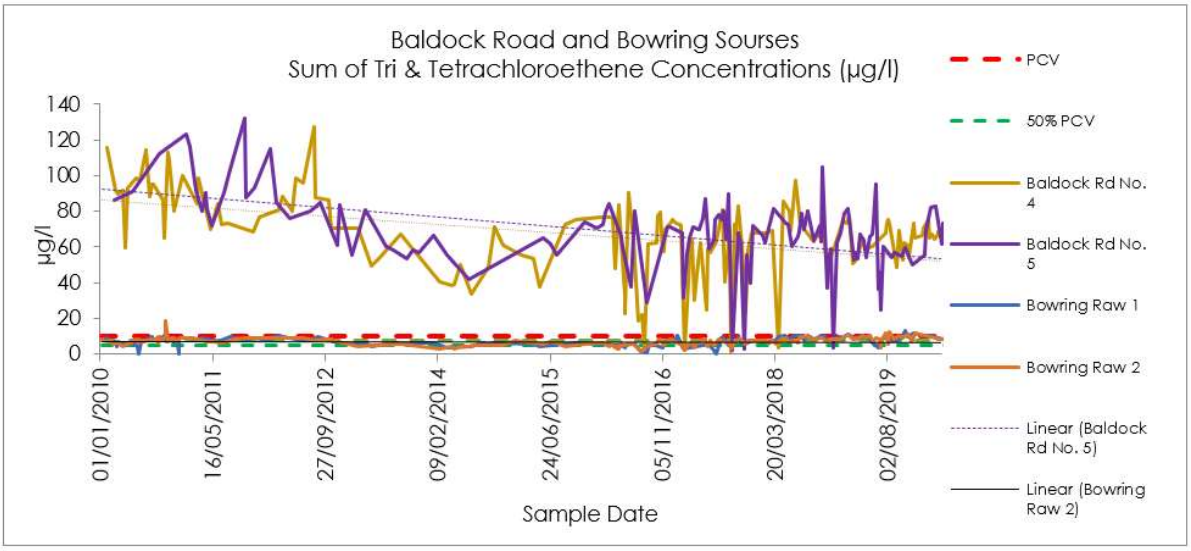

Figure 9. Baldock Road and Bowring Sources Sum tri and tetra-chloroethene concentrations (µg/l).

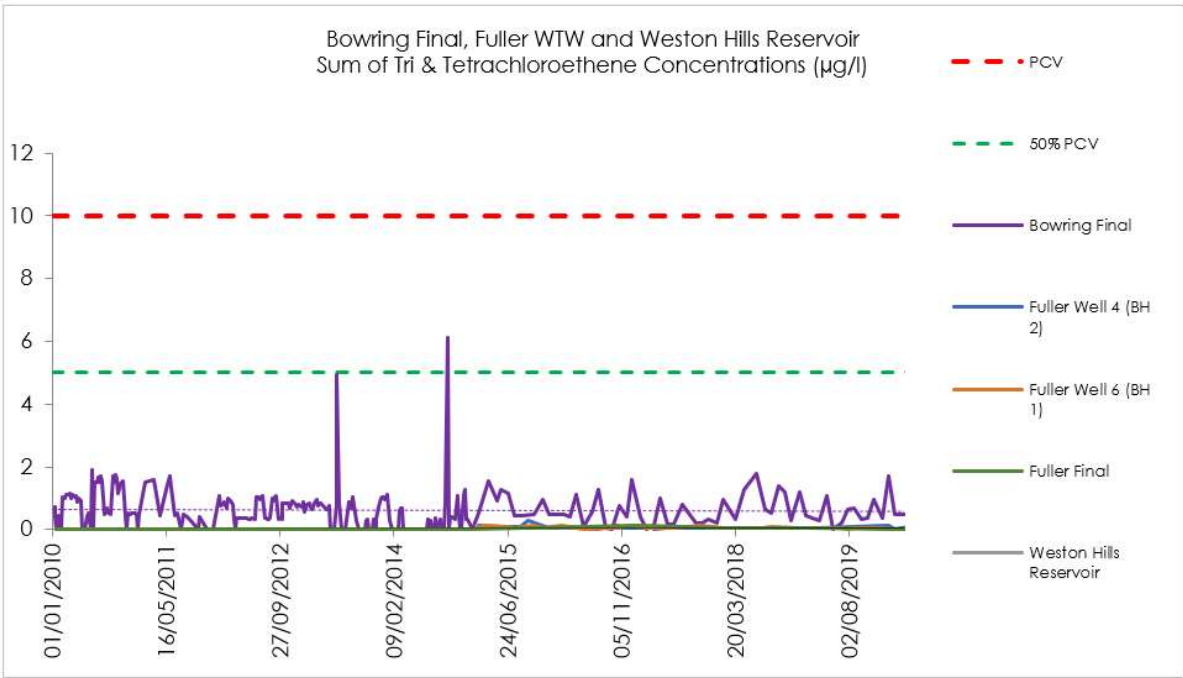

Figure 10. Bowring Final, Fuller WTW and Weston Hills Reservoir Sum tri and tetra-chloroethene concentrations (µg/l).

3. Blackford Sources

The Blackford WTW and sources are situated in a rural area just outside Denham, between the River Colne and the Grand Union Canal. The site has been out of service since early 2021 and will continue to be while nearby HS2 activities are carried out. The water from these sources contains elevated concentrations of manganese, derived from the gravel around the river. Manganese treatment at Blackford has been proposed as part of the WINEP Sustainability Reductions: AMP8 Investments.

The PFOS concentrations detected are stable, around 0.04 µg/l, while the concentrations of PFOA are much higher, around 0.1 µg/l and appear to be on a falling trend over the last decade as shown in the graph below (Figure 11).

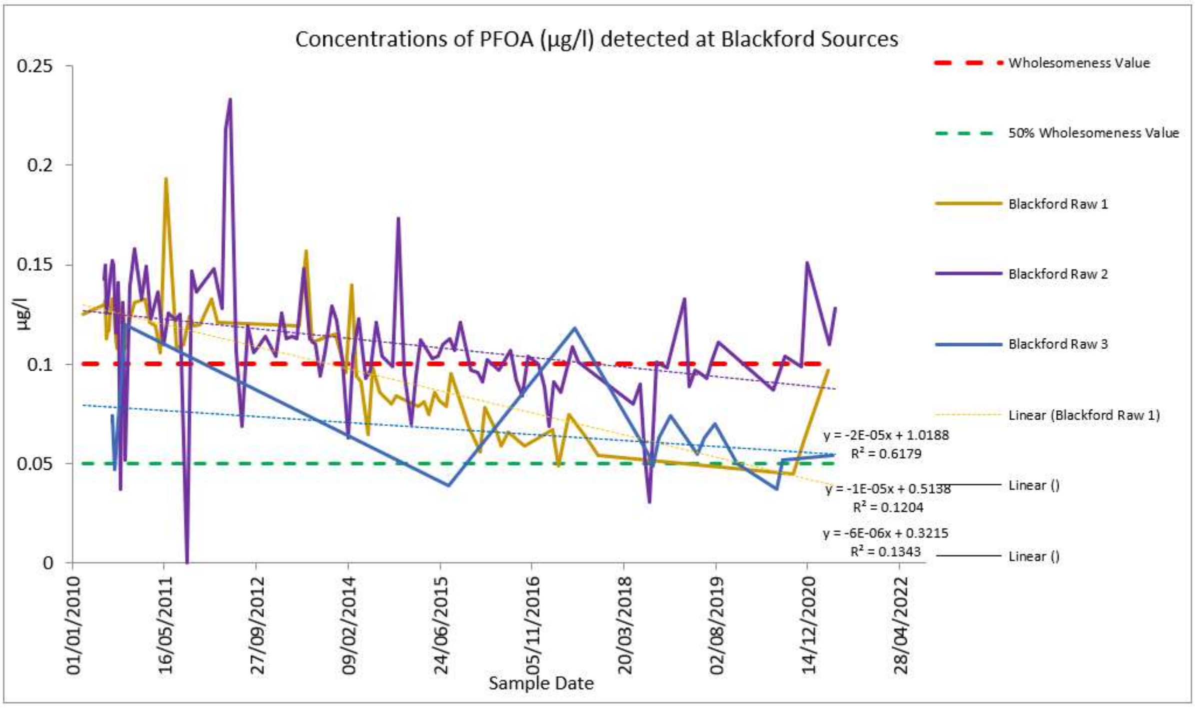

Figure 11. Concentration of PFOA (µg/l) detected at Blackford Sources.

All three sources were showing the concentrations on a decreasing trend, the peak values in raw 1 & 2 were >10 years ago (0.193 µg/l & 0.233 µg/l respectively) and raw 3 peak of 0.12 µg/l was only 5 years ago. These max values are relatively high in relation to the 0.1 µg/l limit.

However, abstractions rates at Blackford WTW have decreased progressively due to a series of reasons (BH rehabilitations works and HS2 enabling works) and it is likely that the decreasing PFOA trends are a consequence of decreasing abstraction rates. Therefore, once abstractions resume to historic levels PFOA concentrations may increase to those seen in 2010, abstraction rates and PFOA concentrations are shown in the graph below (Figure 12).

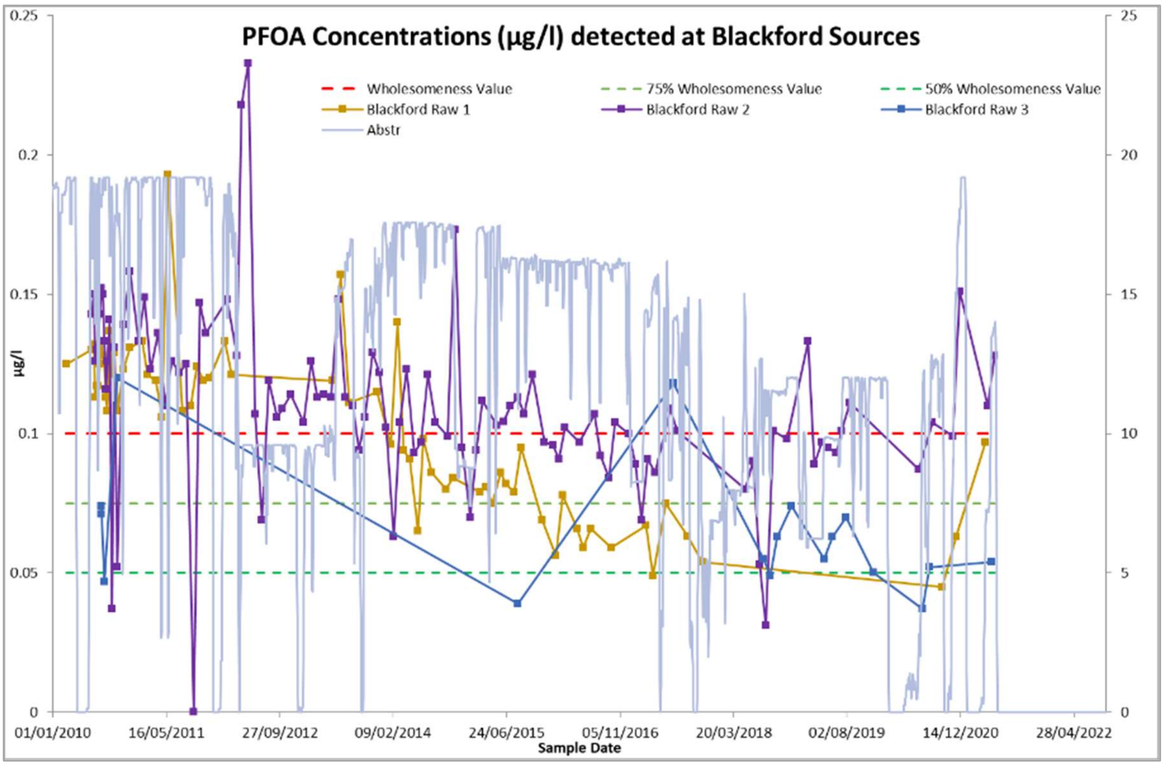

Figure 12. Concentration of PFOA (µg/l) detected at Blackford Sources and Abstraction Rate.

We only have one set of results from the final water, taken at the beginning of May 2021, which were 0.081 µg/l for PFOA and 0.046 µg/l for PFOS. Without some PFAS management on site it is unlikely that the site can be returned into supply.

4. Holywell Sources

The Holywell sources are situated in St Albans, next to the River Ver. They were considered to be one of our most at risk sources from runoff from the fire-fighting activities associated with the Buncefield explosion. The PFOA concentrations detected are generally less than the limit of confidence, 0.009 µg/l, while the concentrations of PFOS are relatively stable 0.04 and 0.07µg/l, two sample results showed concentrations >0.1µg/l 0.118µg/l (12/10/2015) and 0.115µg/l (16/04/2019) in Holywell BH 6. The trends are gradually increasing, as shown in the graph below (Figure 13).

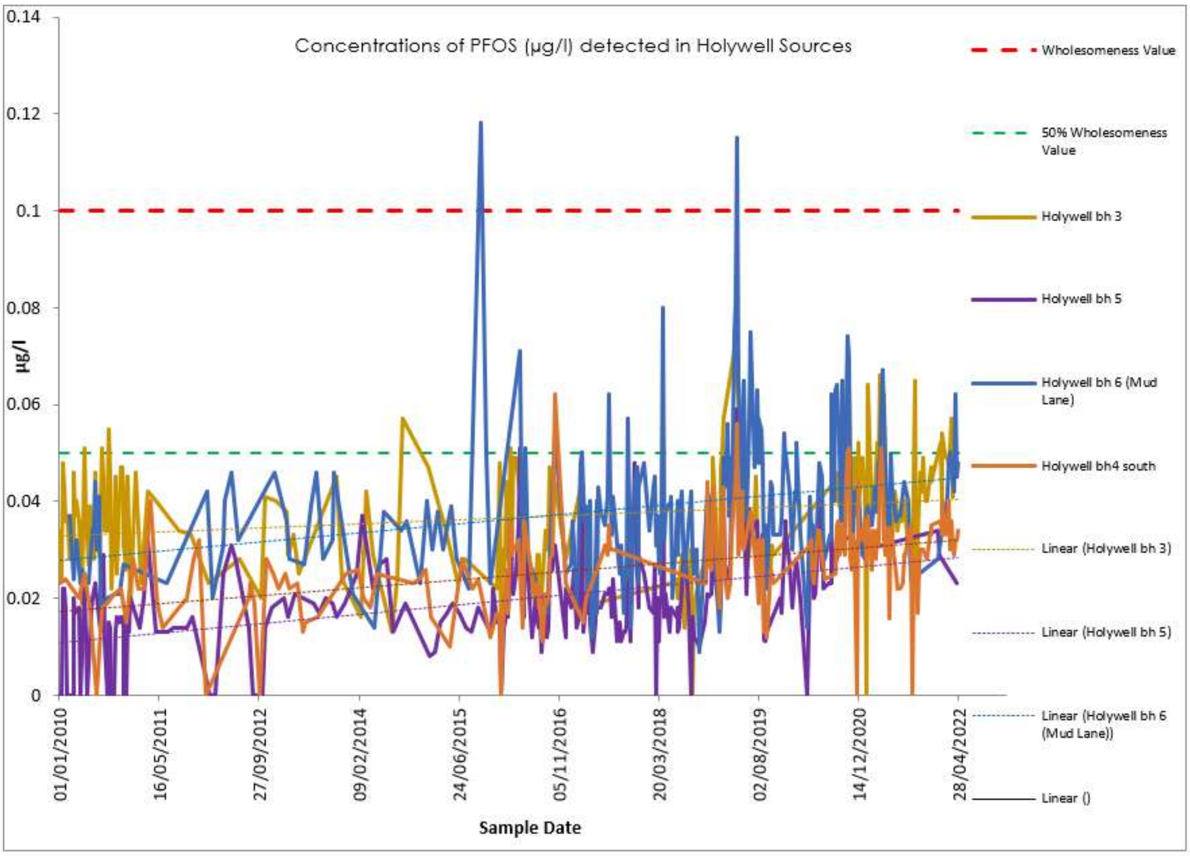

Figure 13. Concentration of PFOS (µg/l) detected at Holywell Sources.

There does not appear to be a change in PFOS concentrations related to abstraction rates and the spikes that occurred in borehole 6 in 2016 and 2019 do not seem to be related to rainfall events. PFOS concentrations and abstraction rates are shown in the graph below (Figure 14).

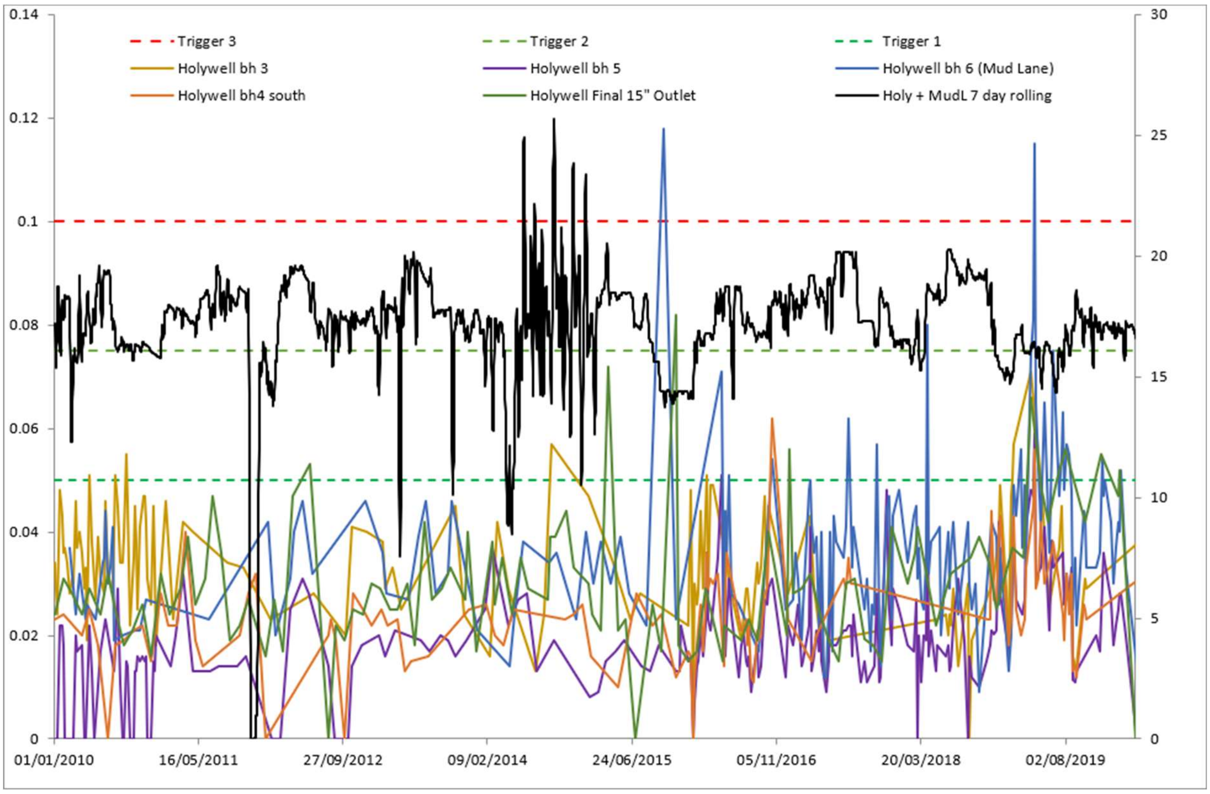

Figure 14. Concentration of PFOS (µg/l) detected at Holywell Sources and Abstraction Rate.

Extended PFAS analysis shows the presence of PFHxS compound with a concentration around 0.027 µg/l. We currently consider the EU20 concentration of PFAS in the drinking water supply from Holywell WTW would be 0.096 µg/l and that treatment would be required to maintain EU sum PFAS concentrations below 0.1 µg/l.

The graph and pie chart below (Figure 15 and Figure 16) show the extended PFAS compound profile seen in the samples taken from Holywell WTW during 2022 to February 2023.

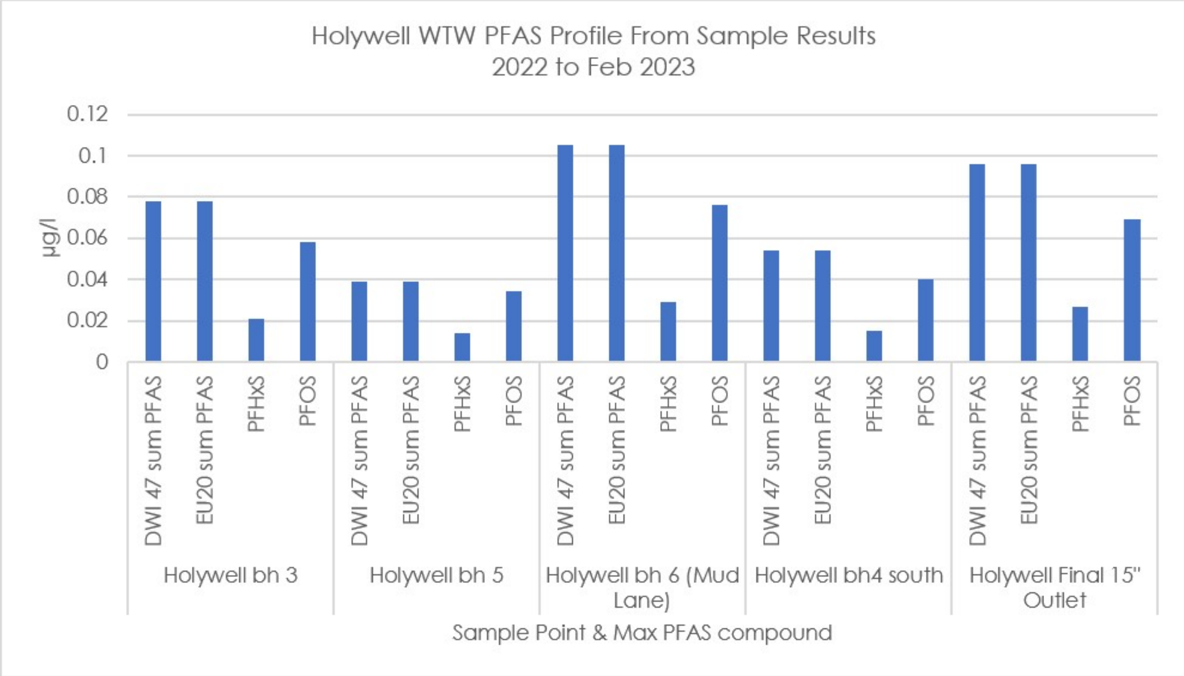

Figure 15. Holywell Water Supply System PFAS Profile 2022 to Feb 2023.

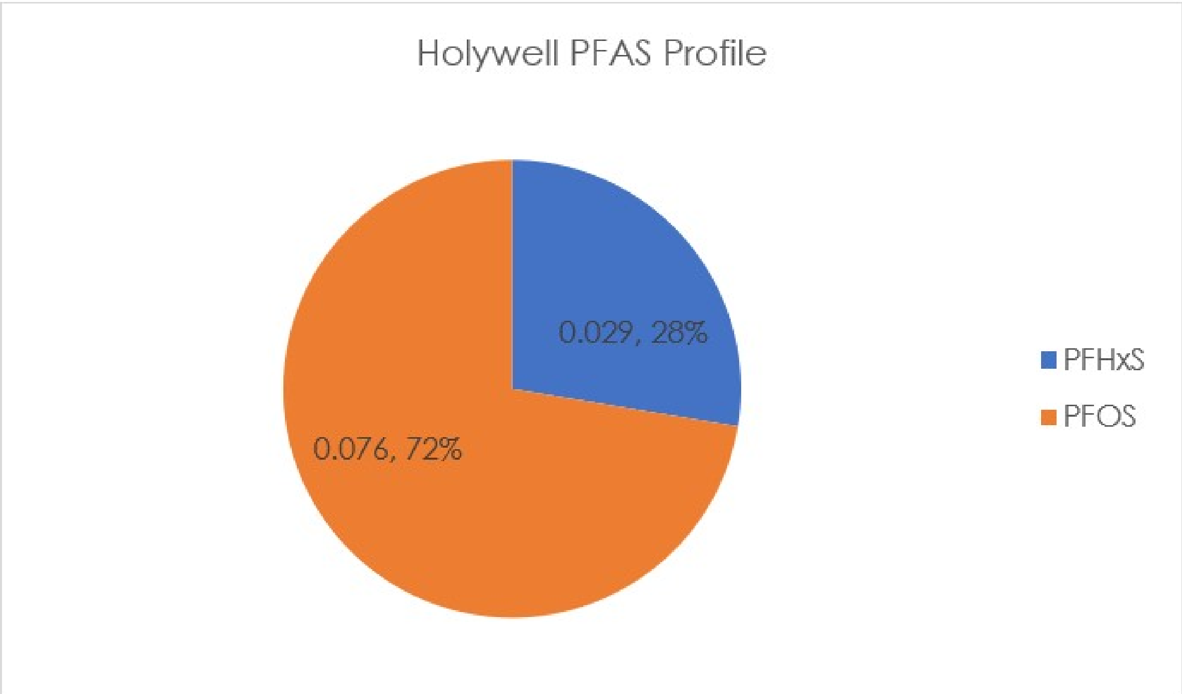

Figure 16. Holywell PFAS Compound Profile.

Holywell WTW has granular activated carbon (GAC) as part of the treatment process which would be expected to remove PFAS. Although originally installed for pesticide removal, pesticide concentrations have decreased over the last decade and GAC is not actively regenerated/replaced. Therefore, GAC shows no removal of PFAS compounds due to saturation. Blending of the source waters within the treatment processes ensures concentrations are less than 0.1 µg/l, but with the concentration of PFOS is showing an increasing trend it is likely that treatment would be required to maintain total PFAS concentrations below 0.1 µg/l.

5. Wheathampstead Sources

The Wheathampstead sources are situated just outside the village of Wheathampstead next to the river Lee. The water from these sources contains elevated concentrations of hexavalent chromium. The PFOA concentrations detected are generally less than the limit of detection, 0.009 µg/l, but the concentrations of PFOS detected are higher and on an increasing trend over the last decade as shown in the graph below (Figure 17). PFOS concentrations detected are now regularly >0.1 µg/l in borehole 2 and on an increasing trend.

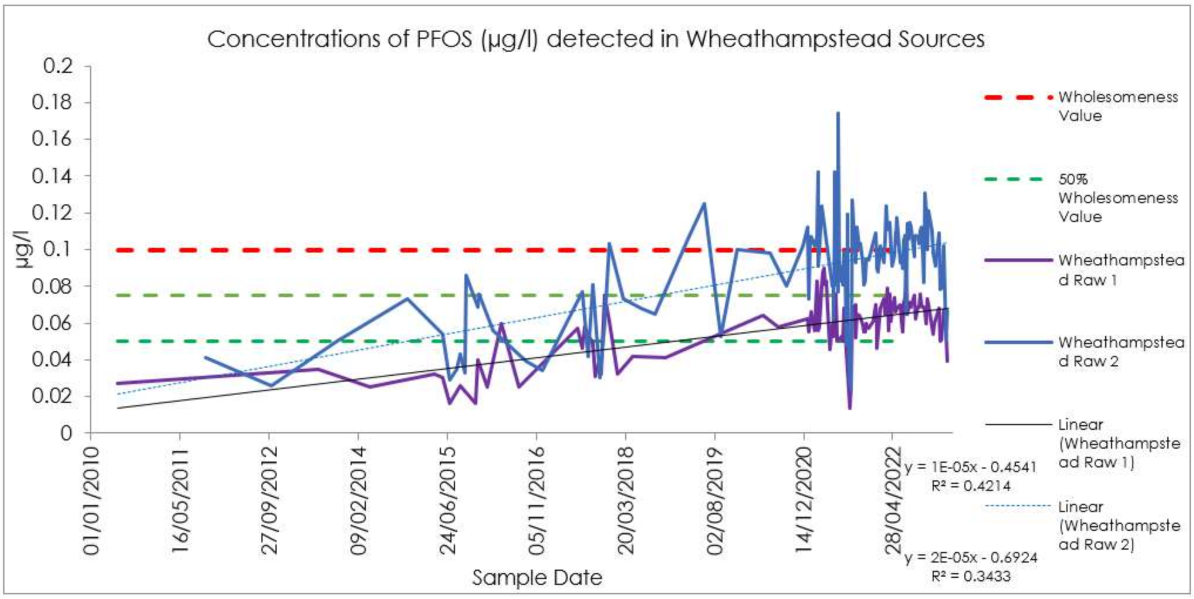

Figure 17. Concentration of PFOS (µg/l) detected at Wheathampstead Sources.

Extended PFAS analysis shows the presence of other PFAS compounds with a concentration around 0.9 µg/l and that treatment would be required to maintain EU sum PFAS concentrations below 0.1 µg/l. The graph and pie chart below (Figure 18 and Figure 19) show the extended PFAS compound profile seen in the samples taken from Wheathampstead WTW during 2022 to February 2023.

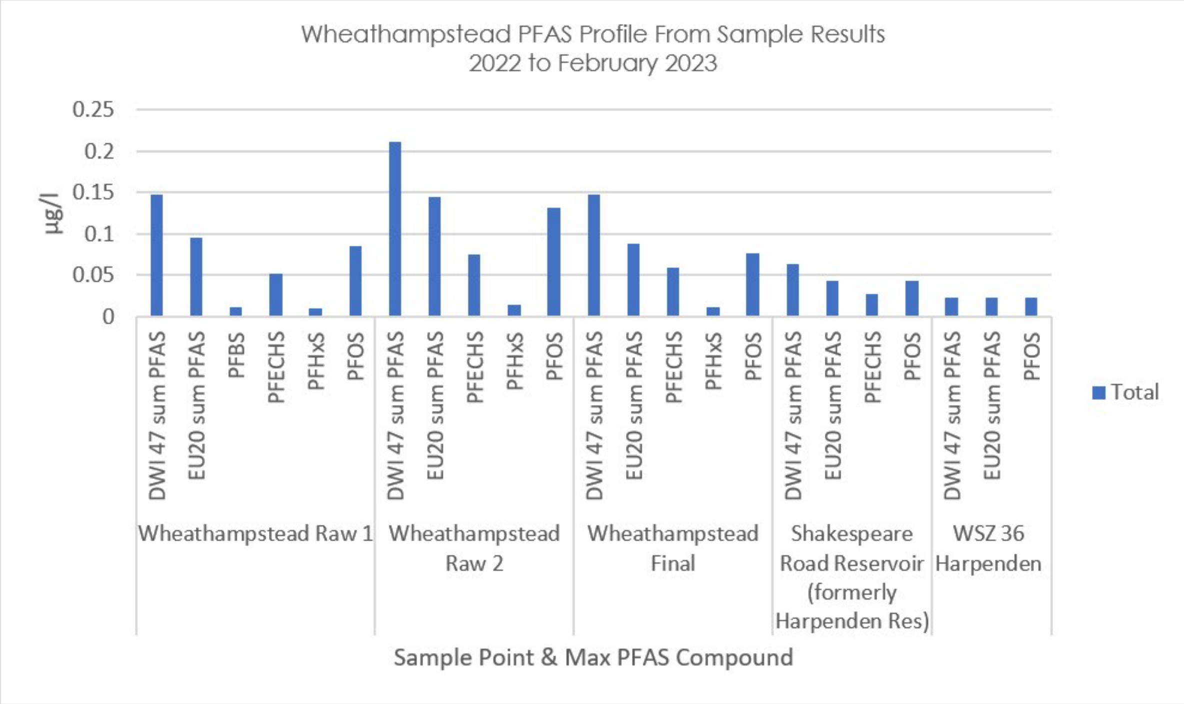

Figure 18. Holywell Water Supply System PFAS Profile 2022 to Feb 2023.

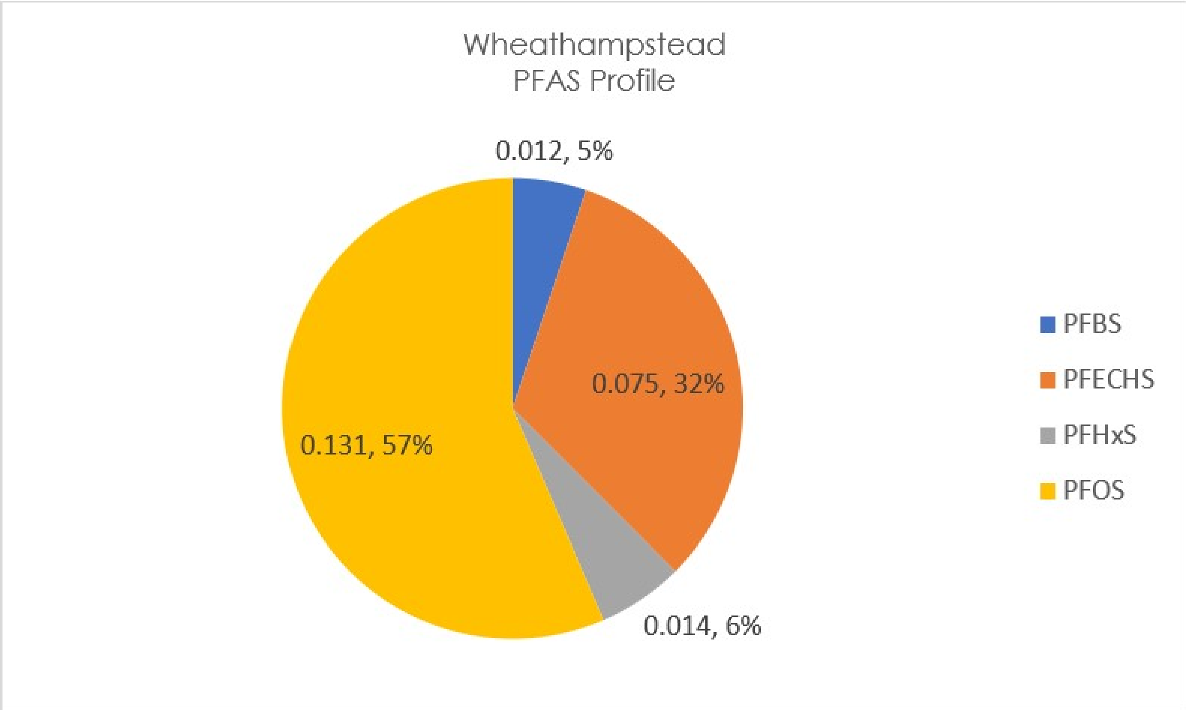

Figure 19. Holywell PFAS Compound Profile.

Only raw 1 is in supply at the moment and the water blends in Harpenden reservoir water from Shakespeare Road WTW so PFOS concentrations going into supply are typically around 0.04 µg/l. If the Shakespeare Road source goes off / fails / is stopped, then Wheathampstead is also stopped.

Work on installing an ion exchange plant for Cr (VI) removal was commissioned in July 2023 to allow water from Wheathampstead to go directly into supply. However, without some PFAS management on site it is unlikely that both boreholes can be returned directly into supply.

There is some evidence from the USA that ion exchange resins remove PFAS. Some limited PFAS performance data from the Chromium IV proposed resin Purolite A600E pilot plant trial work was done and showed show some good removal rates of some PFAS species. There are concerns about the rising trends in PFOS at Wheathampstead and therefore the potential longevity of the plant to achieve the required removal in the longer term.

Problem Statement and Stated Need / Driver

Some PFAS have been identified as being persistent, bio-accumulative in the environment and potentially toxic in terms of human health. The significant reduction in the wholesomeness thresholds has led us to re-evaluate our risk assessments and we have identified four priority water supply systems that require investment to ensure water supplies remain wholesome and to safeguard security of supply and service levels to customers.

Our assessment and optioneering has concluded that several sites (Blackford, Baldock Road/Bowring, Wheathampstead and Holywell) require investment in AMP8 to ensure continued water availability from those treatment works and to safeguard water quality, as well as to gather information to inform future investment decisions.

Risks, Issues and Requirements

Regulatory Position for PFAS in Drinking Water

In January 2021, DWI reissued their guidance in response to more data having become available on the toxicity of PFOS and PFOA. In this guidance the drinking water wholesomeness threshold for both PFOS and PFOA was amended down to **0.1 µg/l (previously 1.0 and 5.0 µg/l respectively).**

The DWI also outlined its expectation that water companies adopt a three-tiered approach to the monitoring and management of PFAS in drinking water supplies. A summary of our assessment of all our raw water sources is provided in Table 4 below.

Table 4. Our tiered assessment of all our raw water sources.

Tier	Tier Trigger Level	No of Sources	Risk Assessment Sum mary
Tier 1: Regulation 27 – Risk assessment	<0.01 µg/l	154	154 Sources Low Risk
Tier 2: Regulation 10 – Sampling: further provisions	0.01 - 0.1 µg/l	49	6 Sources Moderate Risk 43 Sources Low Risk
Tier 3: Regulation 4(2) wholesomeness – concentrations that may constitute a potential danger to human health	>0.1µg/L	Seven: Baldock Road Raw 4 & 5 Wheathampstead Raw 2, Holywell Raw 6 Blackford Raw 1, 2 & 3, (Blackford WTW is out of service)	7 sources High Risk *

*The seven sources are from the four WTWs included in this business case.

Risks

There is currently no risk of prosecution or failing current regulatory standards as we have implemented a comprehensive, risk-based sampling and monitoring programme at all our sources. The frequency of monitoring on each source is determined by the individual risk level. This ensures that we have visibility of changes in raw water quality, and our teams monitor the trends on the water sources to identify any change in risk level.

The risk, therefore, is to water supply and water availability. If the sources were to be turned off due to increasing PFAS concentrations then there would be a decrease in water availability in the area, Table 5 below shows the populations served by the four WTWs. This in turn could lead to low pressure events or, in the extreme, loss of supply to customers.

Table 5. Population Supplied by Treatment Works.

WSZ	DESCRIPTION	TREATMENT WORKS	RESERVOIRS / TOWERS	POPULATION	Comments
1	BALDOCK /LETCHWORTH	Bowring* Fuller* Slip End* * All blended at Weston Hills	Weston Hills Res Weston Tower	50,103	* Calculated on average output (2016-2020) the blend in Weston Hills SR is typically 25% Baldock Road water, 36% Bowring WTW and 39% Fuller WTW water. When Slip End WTW is supplying Weston Hills SR the blend is typically 19% Baldock Road water, 27% Bowring WTW, 30% Fuller WTW water and 24% Slip End WTW water.
47	Ickenham/Denham	Batchworth Iver Blackford	Harefield Res 1 & 2, 3 E&W	48,358	When Blackford is in supply WSZ047 is a blend of approx. Iver WTW 60%; Blackford WTW 30% and Batchworth WTW10%. Our WINEP end of AMP8 plan is to increase the annual average of the group by an extra 11 Ml/d (from 88 to 99 Ml/d) with the annual average at Blackford WTW planned to increase by 3.8 Ml/d (new annual average of 20 Ml/d) to support our WINEP Sustainability Reductions for AMP8.
40	ST ALBANS SOUTH	Holywell		43,309	100% Holywell WTW.
88	ST ALBANS NORTH	Holywell Stonecross	Stonecross Res 1 & 2	53,536	The blend in Stonecross reservoirs is typically 40% Holywell WTW water and 60% Stonecross WTW water.
36	HARPENDEN	East Hyde Shakespeare Road Wheathampstead	Shakespeare Road Res**	39,040	*WTW blend ~ Shakespeare Road WTW = 26%, Wheathampstead WTW = 30% and East Hyde WTW= 44%

However, as more research and health data become available there is a risk that the drinking water wholesomeness threshold for PFAS could be reduced further.

The EU has a more stringent parametric value of 0.1 µg/l for the sum of 20 named PFAS, should this value be adopted, the proposed solutions for our four high risk sites would mitigate this. We have two other sources that show concentrations above the EU sum of 20 which are Tolpits Lane and Roydon BH3, blending and treatment at the WTW currently mitigate the need for investment.

In March 2023 the United States Environmental Protection Agency (EPA) proposed to establish legally enforceable levels for six PFAS known to occur in drinking water[6] (summarised in Table 6 below). The concentrations being proposed would require a further step change if adopted by the DWI.

[6] Per and Polyfluoroalkyl Substances PFAS US EPA

Table 6. EPA proposed regulatory changes.

EPA is proposing a National Primary Drinking Water Regulation (NPDWR) to establish legally enforceable levels, called Maximum Contaminant Levels (MCLs), for six PFAS in drinking water. PFOA and PFOS as individual contaminants, and PFHxS, PFNA, PFBS, and HFPO-DA (commonly referred to as GenX Chemicals) as a PFAS mixture. EPA is also proposing health-based, non-enforceable Maximum Contaminant Level Goals (MCLGs) for these six PFAS.

Compound	Proposed MCLG	Proposed MCL (enforceable levels)
PFOA	Zero	4.0 parts per trillion (also expressed as ng/L)
PFOS	Zero	4.0 ppt
PFNA	1.0 (unitless) Hazard Index	1.0 (unitless) Hazard Index
PFHxS		
PFBS		
HFPO-DA (commonly referred to as GenX Chemicals)		

The proposed rule would also require public water systems to:

Currently, the DWI considers that the guidance limit of 0.1 µg/l for PFAS compounds is robust with an appropriate margin of safety to ensure the wholesomeness of drinking water. So, the treatment options and solutions we have considered are adaptive and a precautionary approach to PFAS for AMP 8.

Another risk is associated with uncertainty of proposed sustainability reductions, any change in groundwater abstractions has the potential to affect our blending capability and ultimately resilience. Table 7 below summarises current proposals:

Table 7. Draft Water Resources Management Plan.

Source	Proposed Sustainability Reductions (SRs) /changes to deployable output (DO)?
Baldock Road Sources	No change in DO for AMP8 but may have SRs in AMP9 onwards for the Letchworth sources. There is an augmentation scheme in the river Ivel that is going to be implemented and the licence will be aggregated to the Letchworth group. The exact amount of the augmentation is not fully defined, as well as the possible impact in licence terms of the group. Any change in groundwater abstractions (reductions) has the potential to affect our blending capability and ultimately resilience.
Holywell Sources	SR planned for end of AMP7 (Dec 2024) to reduce average DO to 9.39Ml/d between Holywell and Mud Lane (no change to the peak DO).
Wheathampstead Sources	No change in DO for AMP8 but may have SRs in later AMPs as part of Environmental Destination scenarios.
Blackford Sources	As part of AMP8 licence relocations, it is proposed to increase the average DO at Blackford from its current level of 16Ml/d to 20Ml/d. This is the same as the current peak DO. This means that Blackford will become a baseload source at 20Ml/d – pumping testing to assess impact post HS2, scheduled to start in 2023. Manganese treatment WINEP Sustainability Reductions: AMP8 Investments Business Case and noted in 'Related Projects' section below.

Allocation of Costs

The delivery of this scheme is driven by a statutory requirement to maintain potable water quality in the context of deteriorating raw water quality conditions and a change in the wholesomeness threshold limit as defined by the DWI. The investment will result in a step-change in the service level provided to consumers and is therefore Enhancement expenditure.

DPC

This scheme is not suitable to be considered for a Direct Procurement for Customers approach as the value is significantly below the £200m TOTEX threshold.

Research, Pilots, and Technology Development

We will make use of the outcomes from several cross-industry research and development trials, learn from the experiences of other water companies who have implemented PFAS removal treatment in AMP7. We will also draw on our own experiences with implementing hexavalent chromium specific ion exchange at Wheathampstead WTW and the GAC treatment at Holywell WTW for PFAS which will be funded by DEFRA Accelerated Infrastructure Programme funding opportunity in the last 2 years of AMP 7.

Wheathampstead WTW:

Wheathampstead hexavalent chromium (project number P019622) is a project that was started in AMP6 and continued into AMP7. We spent £510k in AMP6 and will be c. £5.2m spend in AMP7. It has been funded through our base allowance (not enhancement). The funding was for a new ion exchange plant to be constructed at Wheathampstead to mitigate rising hexavalent chromium concentrations, and in response to change in wholesomeness guidance value.

Trials on the ion exchange treatment during the construction for hexavalent chromium removal demonstrated that it was effective at reducing PFAS concentrations in the raw water too. We will continue to monitor the concentration of PFAS chemicals in the raw, part-treated, and final water at Wheathampstead WTW, to establish a baseline for the efficacy of PFAS removal, regeneration, and bed life of the ion exchange treatment.

It may be necessary to make additional investments in the future (AMP9), for example purchase and install additional resin used in the ion exchange process specifically developed for removal of PFAS compounds or an alternative treatment solution. Therefore, we also propose to undertake research and development of PFAS specific resin to be used in the ion exchange process. We will also monitor DWI Reg 31 ion exchange resin availability.

The scope of the investment identified does not overlap with previous AMPs expenditure as we will be monitoring the effectiveness of the existing ion exchange process and hexavalent chromium targeted media, while in parallel trialling the effectiveness of a new media that is targeted at removal of PFAS compounds. We will make full use of all existing ion exchange assets in the future with a possible change of media depending on the outcomes of the trials.

Holywell WTW:

We proposed the completion of six GAC contactors for media exchange at Holywell WTWs during Year four and five of AMP7 to help establish a baseline for the efficacy of PFAS removal, regeneration, and bed life of the GAC treatment.

The outcome of all this continued learning may be that the solution we implement is different to the preferred and best value solution named above. It will, however, ensure the same level of risk mitigation and protection for our consumers.

Customer Engagement

Detail of Customer Engagement work

We have undertaken extensive engagement with our customers to build a detailed understanding of their priorities and reflected these in this business case. For more detail on our customer engagement see AFW04 What Customers and Stakeholders Want.

We carried out some customer engagement,[7,8,9,10] as part of the Strategic Resource Options programme of work, looking at how customers preferred to be communicated with. This gave us the opportunity to gain some insights into their thoughts and preferences about several of the long-term plans related to water resourcing, including source types.

An evidence review was carried out of 50 documents and stakeholder interviews with each of the water companies, with documents gathered directly from the 6 water companies involved in WRSE, and the evidence was then synthesised to identify consistent findings which were triangulated to assess their strength. During the qualitative phase we tested these findings with 96 household customers across the 6 companies, including Gen Z and vulnerable customer. During the quantitative phase we held 15-minute online surveys with 1,762 household and 198 non-household customers for robust segmentation and validation of findings.

This research reinforced our understanding that water is a low salience topic with our customers, in that they have a low level of awareness and understanding of issues relating to it. This in part is driven by general satisfaction with the customer experience of water in terms of taste, smell and hardness.

We followed this up with some deep dive sessions in July 2022 to specifically test on our own long-term plans with a wide cross section of our customer base[11]. 82 customers and 10 business representatives participated in this research. Customers were divided into "household", "vulnerable" and "future" groups to reflect a range of views, whilst local business representatives provided views on behalf of their place of work ("Non-household").

The Non-household individuals were recruited from businesses which are heavy water users. Customer groups covered a range of ages, socio-economic backgrounds and areas within Affinity Water's region in order to enable a diverse range of views. Given the long-term focus of the research, future customers were also included to gauge an understanding of priorities from individuals who are likely to become Affinity Water customers in the future.

[7] WRSE Customer Preferences Part A Evidence Review Final Report effec ICS February 2021.pdf
[8] Water Club - Changes of Source - June 2022.pdf
[9] Affinity Water Customer Valuation Research Summary Report May 2023.pdf
[10] Affinity Water Customer Priorities for Long-term Ambitions
[11] 'Customer Priorities for long-term ambitions to support PR24 and long-term delivery strategies,' September 2022

Ten online focus groups were held (household and future customers) and fifteen one-to-one interviews conducted (vulnerable and non-household customers). Focus groups were conducted via online video, using the specialist VisionsLive platform, each session lasting 90 minutes. Voting exercises and activities were used throughout the focus groups, to aid engagement, capture strength of feeling, and focus the discussion on the core research questions.

These were qualitative sessions, and the outcomes gave us some insight into customer views of the relative importance to them of, among other considerations:

- Reducing amount of chemicals used in water treatment,
- Reducing carbon emissions associated with treating water for customers,
- Hardness level of their water supply, and
- Keeping customer bills as low as possible.

Finally, we held some quantitative research sessions between February and March of 2023 with a second set of workshops looking at Customer views on priorities covering customer preferences for changing service levels. Customers were generally observed to be more sensitive to avoiding deteriorated service levels compared to the preference for improvements. In general, there was a limited preference for changes in service levels for hard water and hosepipes bans.

911 household customers completed the survey between February and March 2023 800 respondents completed an online survey and 111 completed an in-person interview, qualifying as "digitally disengaged." 42% of the household respondents (383 people) were classified as being in vulnerable circumstances. Around 13% of respondents who took part in the study (117 people) were registered with the Priority Services Register. Of these 117 respondents, 31% were medically dependent on water, 56% suffered from physical issues, and 9% need information in alternative formats.

There was a good distribution among the respondents of all targeted characteristics. Females were slightly over-represented (57% of respondents) and were within +/- 7 percentage of sample quotas. Socio-economic group (SEG) profile were within +/- 3 percentage points of sample quota. All age cohorts were within +/- 4 percentage points of sample quotas.

150 non-household (NHH) respondents completed the survey online. These comprised a good mix of NHHs achieved when measured by both number of sites and by number of employees. Around a third of organisations had only 1 site (34%), 12% of respondents were a sole trader and 15% of respondents had between 100-150 employees. Also, the sample distribution by economic sector has the expected profile with 1% as Primary, 28% as Secondary and 71% as Tertiary.

Evidence of Customer Preferences

We have developed all of this research and analysis into a document called "What our Customers & Stakeholders Want[12]" which presents the findings from the various customer engagement activities. The key takeaway point from the research is that customers have a high level of inherent trust in us as a water provider, and generally are happy for us to make decisions about technology selection and water quality risk management without consultation with them – we are the experts, and they trust us to make those decisions.

Another outcome of the research was a strong steer that customers expect us to meet our regulatory duties at all times, with respect to the Water Supply (Water Quality) Regulations. Any strategic decisions we make with respect to cost or carbon emission reduction must not have any detrimental impact on water quality performance.

The outcomes from the deep-dive qualitative sessions with our own customers indicated that they have wide ranging responses to the questions of whether we should be reducing chemical use in water treatment and whether we should be reducing operational carbon emissions, which could be influenced by many factors including the respondents' own socio-economic group, with no overall preference or point-of-view expressed[13]. Two thirds of customers did not support investment to soften hard water, with a third supporting investment. Hard water tends to polarise customer opinions. However, there was a clear steer from customers, from these qualitative sessions, that their main priority over any of the other considerations was to keep bills as low as practicable.

The SRO customer communication preferences work indicated that there are some acceptance barriers in place for customers around some of our water resourcing ideas, particularly with respect to direct or indirect wastewater effluent reuse schemes. They indicated that they would need reassurance if this type of approach were taken that water would be safe to drink.

The qualitative research sessions indicated that customers were generally observed to be more sensitive to avoiding deteriorated service levels compared to the preference for improvements. Household customer values for improved service levels for areas including tap water aesthetics was relatively modest – but nevertheless improvement in these areas was viewed as beneficial. In general, there was a limited preference for changes in service levels for hard water and hosepipes bans. Respondents felt that Affinity Water's services are good value for money and were generally satisfied with the services they receive.

Customer protection

[12] What our Customers and Stakeholders Want V5 final.pdf
[13] Line of Sight V3.doc

Customers will be protected by the requirements of the Price Control Deliverables (PCD's), and also the requirements of the DWI notices, shown here for Holywell, Reference: AFW-2023-00003:

- Complete GAC media replacement and reinstatement of 3 filters. Date: 30 April 2024
- Complete GAC media replacement and reinstatement of 6 filters (cumulative total from (b) 2). Date: 30 April 2025
- Complete GAC media replacement and reinstatement of all filters at Holywell WTW. Date: 30 April 2026

We will receive a DWI notice for each of the four PFAS-affected sites in relation to our raw water enhancement scheme.

The PCDs will be specified in terms of flow output from each site based on the average DO, and will align with the DWI notice dates.

Achieving the PCDs and DWI notices will deliver all of the customer benefits highlighted in this business case. The Performance Commitments (PCs) that will benefit directly from implementing the proposed protection cover are "Unplanned Outage" and "Water Quality (CRI)". The schemes will also serve to improve resilience, with the associated benefits to ensuring reliable supplies to our customers.

Note that there are no third-party funding arrangements related to these four projects within the PFAS programme of works.

Partnering

Collaboration and Partnering

Engagement with Stakeholders and Partners

- DEFRA (Department for Environment Food and Rural Affairs)

Accelerated Infrastructure Programme (AIP) Opportunity – In October 2022, Defra asked water companies to propose schemes for accelerated additional infrastructure delivery in 2023-24 and 2024-25 that would provide benefits for customers, communities, and the environment. We proposed the completion of six GAC contactors for media exchange at Holywell WTWs during Year four and five of AMP7 and submitted our draft business case to the DWI. In April 2023, Ofwat's draft decision supported the acceleration of the scheme.

- Drinking Water Inspectorate (DWI)

We were invited by the DWI to carry out some early engagement with representatives from the regulator through the Autumn of 2022. We met with them during November 2022 and shared an early view of what is likely to be included in the water quality programme for PR24 and the AIP schemes, their initial feedback was supportive of our proposals.

In January 2023 we submitted a summary statement to the DWI which highlights significant new future risk mitigation measures that we will be seeking support for in the PR24 proposals. The purpose of this statement is to:

    - to understand the justification and evidence for proposals
    - to estimate the number and type of submissions to expect

In addition to the summary paper, in March 2023 we submitted to DWI our draft business cases for drinking water quality investments.

- Environment Agency (EA)

We have liaised closely with the EA to develop our WINEP and catchment management plans for PR24, and have taken a holistic approach at an Operational Catchment scale, incorporating:

- Sustainability reductions (SR's)
- Abstraction Impact Assessments
- Biodiversity enhancement
- Catchment and Nature-based solutions (C&NBS)
    - Revitalising Chalk Rivers - River restoration, habitat enhancement and monitoring
    - Resilient Chalk Catchments - Catchment management measures for multiple benefits (water resources, water quality, biodiversity, carbon, chalk stream resilience.
- Flagship Chalk Stream Catchment Restoration projects (CaBA strategy)

The engagement process is outlined in Figure 20 schematic below.

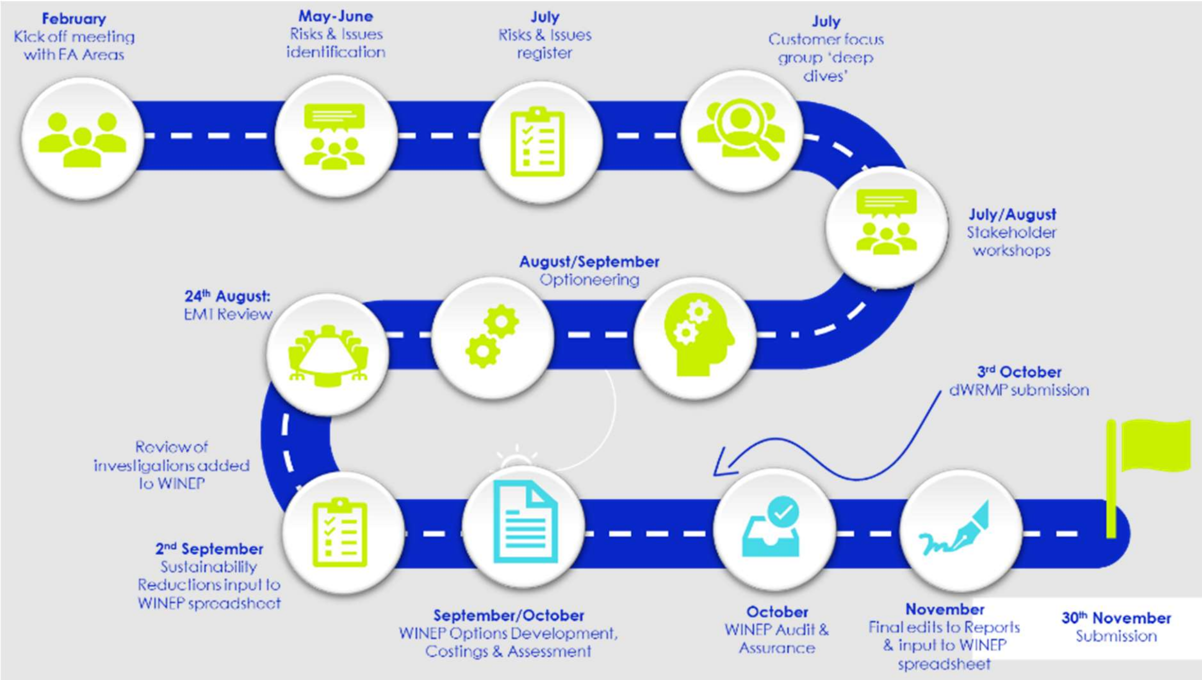

Figure 20. Schematic of our engagement process.

Co-design and Co-delivery

- Inter-company collaboration

We are members of multiple inter-company groups in which we discuss significant emerging risks and potential solutions to or approaches for dealing with them. These include: Water UK (and all the sub-groups therein), UKWIR, WRc (including Disinfection Forum), Cranfield University (including UK Water Network on Potable Water Treatment and Supply), Isle Technologies (Technology Advisory Group, Water Treatment Technical Working Group and Water Distribution Technical Working Group).

- Early engagement with technology suppliers

We have engaged early with suppliers of specialist treatment equipment in order to understand the options currently available on the market, as well as those at various stages of development currently in use in other countries (which may not hold the approvals necessary for use in the UK). We also use information from the suppliers to begin to build up cost estimates for implementation of the novel technologies, for which we do not hold any normalised cost models.

Strategy Development

All of our enhancement cases have been developed as part of our integrated investment portfolio that takes the first steps of our Long Term Delivery Strategy and achieving our ambitions as laid out in AFW03 Strategic Direction Statement.

Long-term Delivery Strategy Alignment

In our Strategic Direction Statement[14] we commit to "Deliver what our customers need, ensuring affordability for all" which encompasses "Exceed[ing] customers' expectations for drinking water." We know that customers hold inherent trust in us to make the appropriate interventions to safeguard their water quality.

There is an additional commitment to "Be prepared for change and resilient to shocks and stresses" within which we commit to "Ensure a resilient supply of water for Affinity Water customers." We are delivering on this commit in this case by providing treatment where no blending or other management of the risk is possible without detrimental effect on the resilience of our supply network in this area.

Our long-term delivery strategy related to water treatment includes an investment line covering "Addressing raw water deterioration." In this instance, there is both a deteriorating (increasing) trend in the concentration of the contaminants in the raw water and newly introduced wholesomeness threshold limits set by the DWI which, in combination, result in a high likelihood that we will need to cease use of these sources for supply within AMP8.

The investments proposed within this business case are aligned with the Core Adaptive Pathway of our LTDS and will not adversely impact any of the potential Alternate Pathways identified within the LTDS. The investments will still be required under all common reference future scenarios.

Treatment Strategy

Currently, our Treatment Strategy requires provision of treatment only when necessary due to raw water quality and when it is the best value holistic solution to provide treatment rather than any other solution.

We are exploring options around selection of treatment processes that have high power demand in preference to processes that require high chemical input in order to reduce our overall operational carbon emissions. The speed at which we implement this strategy will depend on the glidepath to net zero operational carbon emissions set by the Company, and whether these proactive changes towards

[14] AW0031_Strategic-direction-statement.pdf

power-intensive processes away from chemical-intensive processes are necessary to achieve those target future carbon emission profiles.

Adaptive Strategy

Depending on the speed at which we want to reduce our operational carbon emissions on our treatment works, it may be necessary to select a high-power demand process for treatment of PFAS over a high chemical demand process. These operational carbon emissions glide paths will become available to us shortly but are not available right now. For now, we will select best value solution based on cost and risk reduction.

This project is no regrets because we require the water from the sources in order to meet our supply demand balance and, without the addition of treatment processes at these sites, we predict that these sites will otherwise need to be turned off in AMP8. Additionally, the trend for regulation of these compounds is to reduce the allowed concentration (other countries globally have lower permitted limits) as there is deemed to be no safe concentration with respect to human health. Therefore, there is low likelihood that these regulatory limits will be raised again in the medium- to long-term.

Optioneering

We have consistently proposed best value solutions using rigorous optioneering. For more detail on our approach is provided within AFW08 Our Investment Development Process.

An initial review of available treatments for PFAS removal was carried out, with research of the literature and existing practices finding the following options:

- Blending
- GAC
- Ion exchange [either regenerable or non-regenerable],
- Nano Filtration [nF] / RO membranes.

Each of these was evaluated for its advantages and disadvantages using the criteria of capital and operational costs, performance, waste, carbon/environmental impact, and risks. The treatment options were then initially ranked for preference as shown in Table 8 below:

Table 8. Preliminary ranking of treatment options for preference.

Rank	Option	Key Logic	Main Concern
1	Blending	Lower Capex & Opex, low operational input	Control & loss of DO
2	GAC	Good performance, familiar technology, lower risk waste disposal	Some short chain PFAS species, air quality rule changes
3	Non-regen ion exchange	Good performance, medium risk waste disposal	Solid waste disposal
4	Regen ion exchange	Good performance	Waste stream disposal
5	NF / RO membranes	Good performance	Loss of DO, waste stream treatment / disposal, remineralisation may be needed with RO

These findings were in agreement with the GWI (Global Water Intelligence)-sourced maturity matrix which shows the various forms of PFAS treatment in the PFAS technology market (aside from blending) and their associated maturity levels. The findings were then applied to the individual sites that have been identified as needing treatment in AMP8 to assess feasibility and viability, considering any site constraints, other treatment needs, future plans, and impacts on site operability.

The structured Risk and Value (R&V) process has been used for optioneering, which is based on the utilisation of data to identify the best value solutions and/or opportunities. The first phase of the R&V assessment is to fully determine the risks/opportunities for the service to our customers. Once a risk is fully defined, comprehensive root cause analysis is applied to determine the right source of the asset failures and the impact these have on the business. The next phase centres around solution optioneering which identifies alternative solution options, to mitigate/resolve identified risks and opportunities. The Whole Life Cost (WLC) and potential solutions are evaluated using historic costs, and contractor/supply chain knowledge. The WLC is the total cost of owning and operating an asset over its lifetime. It was calculated by adding the initial capital expenditure (Capex) to the operating expenditure (Opex) over 25 years. Finally, the solution options were evaluated using two important metrics: risk reduction and risk index.

Risk reduction measures the amount of risk that is removed by a proposed solution (i.e. initial risk minus percentage risk removed by solution option). Risk index measures the cost-effectiveness of a proposed solution (i.e. WLC of solution divided by residual risk). The lower the risk index the better; the solution with the lowest risk index is the best value option.

By utilising the key outputs from the R&V process the optimum solution can be identified and progressed. The stages and outputs from the R&V process are as follows:

- Problem Definition Statement
- Root Cause Analysis of identified risks
- Unconstrained options – identification of any potential solution options to mitigate/resolve identified risks.
- Feasible options – selection of options to take forward based on practicality, efficacy, and affordability.
- Cost / Benefit ratios, or Risk Index, for each solution

The schemes included in this business case have been monitored and assessed in line with the DWSP risk assessment process as described in the "Project Development" section and have also been considered from a catchment management approach. Analysis of recent water quality data, along with the predicted future trends, has determined that monitoring and catchment management activity on its own is not sufficient to mitigate the risk, and that further intervention is needed.

Selected Options

Do Nothing Option

The "Do Nothing" option for the raw water deterioration sites results in turning each of them off for indefinite periods following exceedance of the PCV, which in turn will affect the supply and demand balance and customer impact risk. As we are employing comprehensive and regular monitoring of the PFAS concentrations in our raw water, our assessment has focused on the predominant risk of water supply/site interruption while factoring in the residual water quality risk. The R&V process quantifies these risks, and each scheme (the four PFAS sites) is evaluated individually to determine if the cost/benefit ratio (risk index) is such that the risk can be tolerated or if intervention is needed.

The R&V process included an assessment of the business impact (Opportunities and Risks Assessment i.e. ORA), considering both risks and opportunities to the business. An example is provided for Baldock Road / Bowring below in Figure 21, and similar examples of the ORA assessments for all four sites can be found in Appendix 1 (note that the cost figures shown here are prior to application of likelihood factors). In the Risk Scoring assessment completed for each of the four sites as shown in Appendix 2, the assessed risk and opportunity costs were weighted to take into account the various likelihoods and real-world challenges that each scenario carried.

AffinityWater — OPPORTUNITY and RISK ASSESSMENT: SUMMARY

Notes: Click on the ? to see the Helpsheet	Units	RISK 1	RISK 2	RISK 3	RISK 4
Only populate relevant green shaded cells		Risk of PFAS WQ failure (> 0.1)	Risk of Unplanned Outage	Risk of water supply interruption or low pressure (reducing supply to Weston Hills Reservoir Storage, as a result of non-wholesome levels of PFAS > 0.1)	Risk of compromised resilience due to reliance on blend with Bowring
Mitigated OPEX ?				£1,022	£2,808
What is the annual value of any mitigated OPEX	£			1021.5	2807.99
Event Risk Index (ERI) ?		£5,572			
What is the ERI seriousness Score?(0-5)?	List	2RegulatoryImpact			
What is the duration of the ERI event?	Hours	168			
How many people are impacted by the ERI event?	No. of people	685			
What is the ERI Assessment Score (1-5)?	List	3RecommendationsMade			
Compliance Risk Index (CRI) ?		£3,155			
What is the CRI Parameter Score (1-5)?	List	5HealthRisk			
What is the CRI Assessment Score (0-5)?	List	3RecommendationsMade			
Which Location is the risk related to?	List	Baldock/Letchworth_WQZ			
C-MeX Risk/Benefit ?					£43,594
What is the expected Improvement/deterioration (Change) in Customer Service Score (CSS)?	Population				22500
What is the expected Improvement/deterioration (Change) in Customer Experience Score (CES)?	Population				22500
Financial, Legal and Reputational Risk (FLR) ?		£10,571			
Amount of penalty or fine if the risk is not mitigated?	£	10571			
Unplanned Outage (AGA related) ?			£19		£3
Which Location is the risk related to?	List		Baldock Road_Source		Baldock Road_Source
If failure occurs, what is the site production capacity reduced to?	Ml/d				
How many days would it take to get production back to peak capacity?	days		7		1
		£19,297	£19	£1,022	£46,404

Figure 21. Example snapshot of R&V process Opportunities and Risks Assessment i.e. ORA of impacts to business.)

Option Assessment

The risk solutions/mitigation options assessed for each of the four sites are summarised under the options headings to follow. Also see Appendix 2 for inserts of desktop R&V Risk Indices tabs.

Also note that the assumed design flows (ML/d) for each of the investments equates to the maximum output license capacity expected of each site in AMP8. These respective site licenses are as follows:

- Baldock Road and Bowring combined: 4.55 + 7.96 ML/d = 12.51 ML/d
- Blackford: 20 ML/d
- Holywell: 20.45 ML/d

- Wheathampstead: 9.71 ML/d

Preferred, Best Value Option

Baldock Road and Bowring PFAS: Granular activated carbon (GAC): install GAC plant on site at Bowring, with media recommended specifically for PFAS removal + enhance existing blending with dilution control i.e. enhanced blending option.

Blackford PFAS: Granular activated carbon (GAC): install GAC plant on site at Blackford, with media recommended specifically for PFAS removal.

Holywell PFAS: Granular activated carbon (GAC): replacing the GAC in all 12 vessels of the existing GAC plant with virgin media recommended specifically for PFAS removal.

Wheathampstead PFAS: Ion Exchange: Monitor performance of existing hexavalent chromium (Cr VI) ion exchange plant, based on (Cr VI) regenerable ion exchange resin for PFAS removal.

R&D pilot trial to investigate effectiveness of alternative resin recommended specifically for PFAS removal.

Least Cost Option

Baldock Road and Bowring PFAS: Granular activated carbon (GAC): install GAC on site at Bowring to treat Baldock Road raw water only (pre-air-stripper), with specialised PFAS removal media.

Blackford PFAS: Ion exchange: New PFAS-specific ion exchange plant, based on non-regenerable Ion exchange resin.

Holywell PFAS: (As Preferred) Granular activated carbon (GAC): replacing the GAC in all 12 vessels of the existing GAC plant with virgin media recommended specifically for PFAS removal.

Wheathampstead PFAS: (As preferred)

Alternative Option 1

Baldock Road and Bowring PFAS: Enhanced Blending with Bowring and Fuller: Existing blending enhanced with tighter control mechanism.

Blackford PFAS: Blending: Install flow meters and control valves in the lines from Blackford to the 12" and 30" mains to always ensure sufficient blending and dilution in both mains.

Holywell PFAS: Enhanced Cross-Blending of Site Boreholes: Blending enhanced with dilution control mechanism, given that there is currently no specific flow or control of the individual BHs to ensure that the correct dilution is achieved.

Wheathampstead PFAS: Ion exchange: Existing hexavalent chromium (Cr VI) ion exchange plant, based on (Cr VI) regenerable ion exchange resin for PFAS removal.

Alternative Option 2

Baldock Road and Bowring PFAS: Ion exchange: New PFAS-specific ion exchange plant, based on non-regenerable ion exchange resin.

Blackford PFAS: Blending: Install blending tank and re-lift pumps on site at Blackford.

Holywell PFAS: Ion exchange: New PFAS-specific ion exchange plant, based on non-regenerable ion exchange resin.

Wheathampstead PFAS: Granular activated carbon (GAC): install GAC on site at Wheathampstead, with virgin media recommended specifically for PFAS removal.

Note that these options were discounted at the initial optioneering stage due to not being practical etc. (least feasible).

The following Table 9 provides a summary of the main assessed options for each of the four sites and their associated costs and rationale.

Table 9. Summary of the main assessed options for each of the four sites and their associated costs and rationale.

Site	Preferred Option Description	Rationale	Preferred Capex Cost (£)	Preferred Opex Cost (£ Annual Average)	Least Cost Option Description	Least Capex Cost (£)	Least Opex Cost (£ Annual)	Alternative Option 1 Description	Alternative Option 1 Capex (£)	Alternative Option 1 Opex (£ Annual)	Notes
Baldock Road & Bowring	Monitor and enhance blending + install new GAC process plant at Bowring to treat both sources' raw water.	Baldock Rd is the main concern but there is also the risk of PFAS at Bowring too (further studies required to assess potential movement of plume). There is also no room at Baldock Road without some re-development of the site.	6,901,272	14,200	Install GAC plant on site at Bowring to treat Baldock Road raw water only (pre-air-stripper), with specialised PFAS removal media.	5,321,198	140,190	Enhanced Blending with Bowring and Fuller: enhanced with tighter control mechanism.	43,600	1,400	
Blackford	Install GAC plant on site at Blackford, with media recommended specifically for PFAS removal.	GAC was the preferred option where treatment is required. Would assist with existing turbidity issue. Potential for a temporary installation to assess PFAS trend. Ave DO increase for AMP8 baseload, dedicated	10,529,802	163,111	Ion exchange: New PFAS-specific ion exchange Plant, based on non-regenerable ion exchange resin.	11,516,012	107,594	Blending: Install flow meters and control valves in the lines from Blackford to the 12" and 30" mains to always ensure sufficient blending and dilution	95,111	1,000	- RE GAC option, site has been off; WQ analysis required for certainty about PFAS levels, but trends had been declining. Additional Manganese and Turbidity issues that need addressing separately. - RE Blending option, difficult to guarantee without

		process required to guarantee output.						in both mains.			water into distribution, and would impact resilience and possibly output. Would need modelling further to determine network modifications required.
Holywell	Reinstating the GAC in all 12 vessels of the existing GAC plant with virgin media recommended specifically for PFAS removal.	Adaptive approach as new treatment would be c.£10m. Already have a total of 12 GACs at Holywell that are no longer used for their original purpose i.e. pesticide removal. GAC method is also the most mature method for PFAS treatment out of the ones assessed.	*277,729	155,111	Reinstating the GAC in all 12 vessels of the existing GAC plant with virgin media recommended specifically for PFAS removal.	*277,729	155,111	Blending enhanced with dilution control mechanism, given that there is currently no specific flow or control of the individual BHs to ensure that the correct dilution is achieved.	84,724	0	Note that AMP7 SR changes being employed at Holywell and Mud Lane which will see reductions in average Deployable Outputs.
Wheathampstead	Monitor existing Chromium (Cr VI) ion exchange plant + R&D	Adaptive approach as new treatment would be c.£6m. Already have an IX plant being	35,343	104,594	Monitor existing hexavalent chromium (Cr VI) ion exchange	35,343	104,594	Monitor existing hexavalent chromium (Cr VI) ion exchange	0	104,594	- RE preferred option (alongside GAC), run BH1 and BH2 together [BH* is lower to blend] and also blend with

	trial for effectiveness of resin recommended specifically for PFAS removal.	commissioned at Wheathampstead so cheaper to utilise existing infrastructure as much as possible.			plant + R&D trial for effectiveness of resin recommended specifically for PFAS removal.			plant, based on (Cr VI) regenerable ion exchange resin.			Shakespeare Rd whilst we monitor effect of new resin on PFAS. - Risk: cannot take Shakespeare Rd res out for inspection under this scenario. Results may indicate the need for treatment. Regen frequency and cost of new resin may be prohibitive over WLC.

*Holywell Capex amount of £277k is for the second six out of 12 GAC media changes and does not include the equivalent amount covered under accelerated funding for the first six GACs across years four and five of AMP7.

Option Assessment Approach

Economic Assessment

An NPV (Net Present Value) analysis (also referred to as CBA or Cost Benefit Analysis) was conducted to assess the total value of the options proposed as investment opportunities to the business. Analysis was undertaken for the preferred option and least cost option for each of the four PFAS-affected sites, and for Baldock Road/Bowring and Wheathampstead an additional alternative option was also assessed. These options were typically based on GAC plant, ion exchange plant and enhanced-blending solutions, or a combination of these in the case of the preferred option for Baldock Road/Bowring.

A standard NPV period of 30 years was used, with a depreciation period of 45 years. Conversely to the R&V, the baseline option was not used as part of the final NPVs; rather, risk mitigation factors were applied to each option's NPV assessment directly, based on the most significant service impacts to the business that were identified from the relevant R&V.

Cost Estimation

The costs that form the basis of the economic assessments have been compiled using a range of sources including site asset information, cost model data including data from third parties such as other water companies, previous projects of a similar nature, and recent quotations, leading to a medium to high level of confidence at this project stage. In this way, the costs were verified both internally and externally a number of times throughout the stages of the assessment process.

The cost model data has been based upon figures applicable to the 2022/2023 financial year, and both quotations and previous project costs are sourced within AMP7. Previous project costs are based on comparable schemes recently delivered or still in delivery. These include Wheathampstead hexavalent chromium ion exchange treatment plant and Stonecross GAC treatment plant.

Benefit Estimation

All risks and benefits were converted into tangible financial benefits by assessing the service impacts to the business and applying appropriate probability factors based on frequency of expected impacts. The ORA and Risk Scoring analyses conducted as part of the R&V assessment, tabulated the risks to the business; while the Solution Optioneering, Solution Impact and Risk Indices stages of the analysis calculated the benefits that each option could potentially bring to the business, based on a number of factors such as the initial risk value, the cost of each option, and the efficacy of each option. In this way, the residual risk was estimated.

Cost Efficiency

Where possible, effort was made to align schemes that were related to each other to save costs. One such example is Blackford, where the site suffers from both PFAS and Iron/Manganese water quality issues and there is urgency to return the site to service following decommissioning due to HS2-related works. In the spirit of cost efficiency, we will carry out construction of both the PFAS treatment and Iron/Manganese treatment plants concurrently and right from the first year of AMP8.

Another cost-efficient saving was realised in our assessment of Holywell's existing infrastructure. After assessing and confirming that the existing GACs are no longer required for their original purpose due to a change in the water quality of the source water they were intended to treat, costs were compiled to re-purpose these assets with minimal changes to the existing setup.

Cost efficiencies were also employed in the form of forward design planning across the options for each site. For the Baldock Road/Bowring site, design variations of initial options were considered such as the placement of the GAC treatment, to ensure the solution is the most effective and efficient form of treatment. In doing this, the preferred solution was designed to eliminate the significant costs that could arise from the GACs being saturated with VOCs (Volatile Organic Compounds) if treated before the Air-Stripper at Bowring, in addition to PFAS. This preferred option also proposes to enhance the existing blending from the beginning of AMP8 to manage the risk, and then supplement this with the bulk of the risk mitigation by way of construction of the GAC plant in years three and four. This will optimise Opex costs during the construction of the asset.

At Wheathampstead, cost savings have been considered particularly for the ion exchange options. The preferred option proposes to utilise the existing hexavalent chromium plant which is planned to be commissioned mid-2023. This solution allows the significant saving of costs that otherwise would be associated with the building of a new plant.

Assumptions Made

The lifespan of the options was assumed based on a combination of empirical average estimates and supplier information. This was applied to the R&V and the NPV assessments.

For the relevant sites' options, assumptions had to be made regarding the practicalities of their delivery that may affect aspects such as maintenance and therefore Opex costs. One such example is for Baldock Road/Bowring where the preferred option is a result of assuming the worst-case scenario using the information currently available, in that the solution has been sized to treat both sites' raw water sources after the air stripper to avoid possible increased frequency of GACs saturation. Another example is for Wheathampstead ion exchange options where again saturation of the hexavalent chromium resin (and therefore the associated maintenance/Opex costs) are assumed to be double that normally expected. It has been assumed that any planning permissions will be granted as required.

Uncertainties and Sensitivity Analysis

Relating to the Wheathampstead preferred option, the uncertainty around this solution is based on the increased likelihood that the hexavalent chromium plant's resin will become saturated at a higher rate due to both trialling its effectiveness against PFAS as well as it's intended normal treatment of hexavalent chromium. This uncertainty has been mitigated by factoring in the expected additional Opex based on increased resin regeneration frequency. The effectiveness of the hexavalent chromium-specific resin against PFAS is still to be properly assessed (as part of the preferred option). This has been reflected in the efficacy factor prescribed to this solution option during the R&V assessment stage.

Given that the NPV assessment process was preceded by the R&V analysis conducted for each of the four sites respectively, the NPV assessments also served as a more in-depth whole life analysis by effectively repeating the economic assessment elements of the R&Vs, to reinforce the outcome of the R&Vs while at the same time showing the practical financial benefits of the assessed investments to the business.

In addition to the above, the following uncertainties apply:

New main routes subject to survey and change. Mitigation: costs build-up has factored in the demands that may accompany the foreseen risk scenario, based on significant experience of laying new mains. An example of this would be allowing for the cost of liaison with potential landowners in the event of easement requirements.

Supply chain - availability of components to build the solution within planned project timescales. Mitigation: framework agreements to be utilised where possible, and early liaison with suppliers.

Other utility company work plans + internal unplanned work – potential overlap of works creating potential delays. Mitigation: the optioneering process has considered and aligned where possible with known planned projects, in order to deliver the works as efficiently as possible. Blackford is an example of this, where the raw water also suffers from Manganese/turbidity; the proposed pressure filter system to treat the Manganese meant that the footprint had to be considered alongside the GAC option for PFAS.

Significant increase in PFAS levels earlier than forecast, accelerating the urgency of the proposed solutions. Mitigation: partly mitigated through ongoing monitoring in place at sites identified to be at-risk, and where possible exploring different design options such as location of GAC treatment at Bowring.

We have made conservative estimates for when benefits will start and finish, and how they increase and decrease over time. As such, our economic analysis is inherently conservative by nature. We then consider the benefit metric for sensitivity studies as this becomes the most material uncertainty in the analysis. A sensitivity analysis was conducted as part of each CBA for the PFAS sites, using the goal seek function within our spreadsheet to determine the value of a metric of concern that would be required to make the scheme cost beneficial. This provides a sensitivity check on the metric and enables commentary on the reasonableness of the economic analysis. We have run sensitivity checks on all significant benefit metrics.

In order to mitigate against project uncertainties and to avoid potential double-counting we have integrated of all of our infrastructure business cases with our over-arching network strategy to identify synergies and delivery efficiencies.

Carbon Assessment

Embodied carbon figures for each scheme were built from bottom-up unit cost models. Operational carbon was calculated from energy use. These are combined to give a whole life carbon assessment for each scheme's preferred option and other viable options to form part of the selection process.

Across the four PFAS sites with the exception of Baldock Road / Bowring, the blending solution (as a standalone solution) was ruled out as a viable risk mitigation option, mainly due to the accompanying resilience risk as well as this option's inability to sustain sufficient PFAS-dilution and therefore limiting site output. For these reasons, the blending option was not considered in the relevant carbon calculations below.

The following carbon summary tables (Table 10, Table 11, Table 12, Table 13) show the relative calculated carbon related to each solution. The listed option numbering that precedes each table is solely for the purpose of identifying each solution in the Carbon spreadsheets, and so their numbering may not match that of the R&V or NPV assessments.

Baldock Road / Bowring Carbon Results

"Option_1" – New GAC Plant dual-treatment

"Option_2" – Blending with dilution control.

"Option_3" – New GAC Plant Baldock Raw only

"Option_4" - New Ion exchange Plant

Table 10. Carbon summary tables for Baldock Road / Bowring, showing the relative calculated carbon related to each solution.

Embodied Carbon (kgCO2e)

	Option_1	Option_2	Option_3	Option_4
Total	867,547	795	535,619	592,562
Total Civil Works	412,493	-	219,762	460,099
Total M&E	455,054	212	315,857	115,029
Total ICA	-	582	-	17,434

Operational Carbon (kgCO2e/year)

	Option_1	Option_2	Option_3	Option_4
Total	49,240	298	17,712	17,712
Total Energy related (excludes transport)	49,240	298	17,712	17,712
Total Non-Energy related (includes transport)	-	-	-	-

Total Whole Life Carbon (TCO2e) **40 years**

	Option_1	Option_2	Option_3	Option_4
Embodied Carbon	340	0.40	211	229
Operational Carbon	12	0.07	4	4
Total Whole Life Carbon	352	0.48	215	233

Blackford Carbon Results

"Option_1" – New GAC Plant

"Option_3" – New Ion exchange Plant

Table 11. Carbon summary tables for Blackford, showing the relative calculated carbon related to each solution.

Embodied Carbon (kgCO2e)

	Option_1	Option_3
Total	1,169,495	1,038,921
Total Civil Works	590,977	791,659
Total M&E	578,519	229,828
Total ICA	-	17,434

Operational Carbon (kgCO2e/year)

	Option_1	Option_3
Total	78,720	78,720
Total Energy related (excludes transport)	78,720	78,720
Total Non-Energy related (includes transport)	-	-

Total Whole Life Carbon (TCO2e) 40 years

	Option_1	Option_3
Embodied Carbon	457	400
Operational Carbon	20	20
Total Whole Life Carbon	476	419

Holywell Carbon Results

"Option_1" – Repurposing existing GAC Plant

"Option_3" – New Ion exchange Plant

Table 12. Carbon summary tables for Holywell, showing the relative calculated carbon related to each solution.

Embodied Carbon (kgCO2e)

	Option_1	Option_3
Total	143,952	1,038,921
Total Civil Works	5,593	791,659
Total M&E	138,359	229,828
Total ICA	-	17,434

Operational Carbon (kgCO2e/year)

	Option_1	Option_3
Total	-	80,492
Total Energy related (excludes transport)	-	80,492
Total Non-Energy related (includes transport)	-	-

Total Whole Life Carbon (TCO2e) 40 years

	Option_1	Option_3
Embodied Carbon	58	400
Operational Carbon	-	20
Total Whole Life Carbon	58	420

Wheathampstead Carbon Results

"Option_1" – Existing Chromium (Cr VI) IX plant + R&D

"Option_2" – New Ion exchange Plant

"Option_3" – New GAC Plant

Table 13. Carbon summary tables for Wheathampstead, showing the relative calculated carbon related to each solution.

Embodied Carbon (kgCO2e)

	Option_1	Option_2	Option_3
Total	173,308	949,990	706,151
Total Civil Works	78,063	780,627	300,265
Total M&E	93,502	151,928	405,886
Total ICA	1,743	17,434	-

Operational Carbon (kgCO2e/year)

	Option_1	Option_2	Option_3
Total	3,822	38,219	38,219
Total Energy related (excludes transport)	3,822	38,219	38,219
Total Non-Energy related (includes transport)	-	-	-

Total Whole Life Carbon (TCO2e) 40 years

	Option_1	Option_2	Option_3
Embodied Carbon	68	364	277
Operational Carbon	1	10	10
Total Whole Life Carbon	69	374	287

Biodiversity Net Gain (BNG) Assessment

Biodiversity Net Gain (BNG) cost figures for each scheme were derived by applying a representative percentage value to the Capex costs of each relevant solution option based on internal analysis. The percentage factor in this calculation varies depending on the Capex cost in question and the BNG classification of the site.

BNG is derived from a metric created by Defra, which classifies types of habitats and their condition to give a unit score for a given site being worked on. UK Hab is the methodology that is used to classify the habitats and conditions within the metric, which is nationally used across the ecology industry.

This was then verified against previous similar project BNG costs where available, to ensure that the estimated costs were not an underestimate or greatly different from what would be expected. This assessment was completed for each scheme's preferred option and other viable options that required consideration of BNG, to form part of the selection process; note that only the preferred (GAC) options for Blackford and Baldock Road / Bowring were relevant for this assessment as shown in the following Table 14.

Table 14. BNG calculation table for all treatment (GAC and ion exchange) options; only the two BNG-affecting preferred options (GAC treatment for Baldock Road / Bowring and Blackford) not greyed out.

Business Case	Owner	Scheme	AMP8 Capex (£)	Special Site / Habitat	Site %	Biodiversity Capex (£)	Notes
Raw Water Deterioration		Raw Water Enhancement: Baldock Road PFAS (3x GACs Baldock-Only Treatment Option at Bowring)	£ 5,321,198	N	1.0%	£ 53,212	Not Preferred Option
Raw Water Deterioration		Raw Water Enhancement: Baldock Road PFAS (8x GACs Combined Treatment Option)	£ 6,901,272	N	1.0%	£ 69,013	Preferred Option
Raw Water Deterioration		Raw Water Enhancement: Baldock Road PFAS (IX Treatment Option)	£ 4,966,671	N	1.0%	£ 49,667	Not Preferred Option
Raw Water Deterioration		Raw Water Enhancement: Blackford PFAS (12x GACs Treatment Option)	£ 10,529,802	Y	1.5%	£ 157,947	Preferred Option
Raw Water Deterioration		Raw Water Enhancement: Blackford PFAS (IX Treatment Option)	£ 11,516,012	Y	1.5%	£ 172,740	Not Preferred Option
Raw Water Deterioration		Raw Water Enhancement: Holywell PFAS (GACs Treatment Option)	£ 277,729	Y	2.5%	£ 6,943	N/A (Existing GAC Plant)
Raw Water Deterioration		Raw Water Enhancement: Holywell PFAS (IX Treatment Option)	£ 11,723,330	Y	1.5%	£ 175,850	Not Preferred Option
Raw Water Deterioration		Raw Water Enhancement: Wheathampstead PFAS (GACs Treatment Plant Option)	£ 6,317,290	N	1.0%	£ 63,173	Not Preferred Option
Raw Water Deterioration		Raw Water Enhancement: Wheathampstead PFAS (New IX Treatment Plant Option)	£ 3,225,268	N	1.0%	£ 32,253	N/A (Potentially required/not required for PFAS trial/pilot plant alongisde existing IX Plant for Cr VI)

Third Party Assurance and Audit Trail

There has been internal assurance and review through the steering group. The business case has also undergone an independent audit by a consultant.

Liaison with AW Production and physical site visits form the basis of all individual site option requirements. Costs have been compiled and averaged/verified by multiple sources such as quotations, cost models and information from previous similar projects.

The Desktop R&V and NPV assessments have undergone similar internal governance and assurance processes, through regular review meetings with the Asset Planning Manager.

A full R&V workshop, with all key stakeholders will be held to review the risks and potential solutions using up to date data, followed up by site specific quotes from the vendors which will be used to gain financial approval to progress the solution.

The cost models in particular are based on data from other businesses in the water industry which further strengthens the reliability of the data. The carbon model data used is also based on ongoing information sharing with Mott MacDonald.

Option Assessment

Commentary on the Economic Assessment

An NPV analysis was conducted to assess and compare the total value of the investment options shortlisted. Analysis was undertaken for the main options for all four PFAS sites. These options consisted of the main treatment methods that make up the preferred options, namely GAC treatment with PFAS-specific media and ion exchange resin (both hexavalent chromium and PFAS-specific alike), and enhanced blending to dilute the PFAS levels.

The R&V initial analysis determines the best value options based on cost, residual risk and calculated whole life costs.

The effective good value options were then assessed using NPV.

The NPV assessments also served as a sensitivity analysis by effectively repeating the economic assessment elements of the R&Vs to reinforce their outcome while at the same time showing the practical financial benefits of the assessed investments. A standard NPV period of 30 years was used, with a depreciation period of 45 years. Unlike for the R&V, the baseline option was not used as part of the final NPV assessments; rather, risk mitigation factors were applied to each option's NPV assessment directly, based on the most significant service impacts to the business that were identified from the relevant R&V. NPV Assessment / CBA summary tables for PFAS sites are shown below Table 15.

Table 15. NPV Assessment / CBA summary tables for PFAS sites.

Baldock Road / Bowring PFAS Options	Total NPV	Total NPV Benefits	Benefit/Cost
New GAC Plant dual-treatment + Blending	£3.9M	£11.1M	1.5
New GAC Plant Baldock Raw only	-£0.940M	£5.6M	0.9

Blackford PFAS Options	Total NPV	Total NPV Benefits	Benefit/Cost
New GAC Plant	£3.5M	£8.8M	1.3
New IX Plant	£2.8M	£14.2M	1.2

Holywell PFAS Options	Total NPV	Total NPV Benefits	Benefit/Cost
New GAC Plant	£1.1M	£17.8M	5.6
Blending with dilution control	£0.085M	£0.356M	4.7

Wheathampstead PFAS Options	Total NPV	Total NPV Benefits	Benefit/Cost
Existing Chromium (Cr VI) IX plant + R&D	£4.4M	£6.31M	3.2
Blending with dilution control	£0.012M	£0.063M	1.2

Preferred, Best Value, Option

Baldock Road and Bowring PFAS:

- The PFAS GAC Plant (dual-raw-source treatment) is the overall best value option as it provides the highest risk mitigation by reducing the PFAS concentrations back within the safe limit and is more resilient due to there being no dependency on a secondary site to provide additional water to deliver the blend to dilute the PFAS level. The Enhanced Blending option has been combined with the GAC plant solution as the overall preferred solution, to be implemented at the offset of AMP8 due to having the lowest carbon footprint of the options, as well as the lowest Opex costs while still providing some risk mitigation.
- This solution has been developed as the preferred option, considering aspects of design such as placement of the treatment at Bowring within the existing process

and how that could increase our Capex and Opex cost, as shown in the Optioneering section's summary table above.

Blackford and Holywell PFAS:

- The PFAS GAC Plant is the overall best value option as it provides the highest risk mitigation by reducing the PFAS concentrations back within the safe limit and is more resilient due to there being no dependency on a secondary site to provide additional water to deliver the blend needed to dilute the PFAS level. Holywell in particular benefits significantly from the existing GAC infrastructure and this is reflected in the NPV assessment, as can be seen from the preceding summary table. Any existing blending has been assumed to continue at the very least until the GAC plants have been commissioned into service in AMP8.

Wheathampstead PFAS:

- The existing hexavalent chromium ion exchange plant (in combination with a R&D trial of a PFAS-specific ion exchange plant) is the overall best value solution as it provides the risk mitigation by reducing the PFAS concentrations back within the safe limit without the need for significant capital outlay. It is also a resilient option due to there being no dependency on a secondary site to provide additional water, which would normally be required to deliver the blend to dilute the PFAS level. This option benefits significantly from the existing Cr IV plant infrastructure and this is reflected in the NPV assessment, as can be seen from the preceding summary table.

General Approach Commentary:

- Across all preferred options for the four sites, the main benefit is that the risk mitigation proposed is to fulfil a regulatory requirement that the business must adhere to. The alternative option to doing something now would be to delay implementation of the proposed solutions by an AMP, which would only increase the risk as WQ conditions worsen and would only see implementation costs rise significantly. The Financial Benefits section of the NPV assessments have factored in the assumption of a five-year delay and a corresponding 10% cost increase. Additionally, if there was an event, the business would essentially end up having to spend a similar amount anyway.

- The main Service Benefit to the business is factored into the NPV assessments as mitigating loss of site output capacity (based on the capacity of the sites), using Ofwat values (£'s) and applying a risk factor that is dependent on the solution.

- Additional benefits to the business include the avoidance of regulatory penalties, reputation decline and additional Opex costs, and mitigation of the would-be higher risk of problems at other sites. Another key benefit that relates to the performance commitments of the business is CRI (Compliance Risk Index) performance. This directly reflects the business's water quality performance and is affected by treatment failure, which the preferred option will mitigate significantly.

Least Cost Option

Baldock Road and Bowring PFAS:

- The PFAS GAC Plant (Baldock-raw-source-only treatment) is the most viable least cost option from a five-year Capex and Opex perspective, however the NPV assessment calculated that this alone would be less cost-beneficial than the preferred option over the NPV period. There is also significant uncertainty around how the GACs will react to the solvents in the Baldock Road raw water, which is usually treated at the Air Stripper at Bowring along with Bowring's own raw water. Research has shown that a pre-air-stripper setup will likely result in lack of protection against the risk of GAC media saturation/Opex issues, as well as the risk of movement of the PFAS plume to the Bowring sources. For this reason, along with the fact that the NPV benefits are significantly lower, the single-source treatment option has been ruled out in favour of the hybrid preferred solution.

Blackford PFAS:

- The PFAS IX Plant is the most viable least cost option from a Capex and Opex perspective, however the NPV assessment calculated that this alone would be less cost-beneficial than the GAC option. There is also significant uncertainty around the obtainment of DWI Reg 31 approval which is required. For this reason, along with the fact that the NPV benefits are significantly lower, the single-source treatment option has been ruled out in favour of the hybrid preferred solution.

Holywell PFAS: Most viable least cost option is the preferred option.

Wheathampstead PFAS: Most viable least cost option is the preferred option.

Alternative Option 1

Baldock Road and Bowring PFAS: N/A

Blackford PFAS: N/A.

Holywell PFAS:

- The Enhanced Blending solution, although one of the cheapest options at a glance, was ruled out by Holywell's NPV assessment calculations as being non-cost-beneficial on its own. For this reason, along with the fact that the Total NPV Benefit of this solution is significantly lower, the Enhanced Blending option has been ruled out in favour of the GAC preferred solution.
- With PFAS concentrations increasing, the Blending option will no longer be viable in AMP8 as the combined peak output of all constituent sources for Holywell would be insufficient to dilute the PFAS levels below the safe level. Furthermore, in the event of a shutdown at the respective blend sites, Holywell would also need to

be shut down to prevent the unwholesome high-PFAS-concentration water from entering supply.

Wheathampstead PFAS:

- The Enhanced Blending solution, although one of the cheapest options at a glance, was ruled out by the Wheathampstead NPV assessment calculations since the Total NPV Benefits are significantly lower than the hexavalent chromium Plant / R&D preferred solution.

- With PFAS concentrations increasing, the Blending option will no longer be viable in AMP8 as the combined peak output of both constituent sites (Wheathampstead and Shakespeare Road) would be insufficient to dilute the PFAS levels below the safe level. Furthermore, in the event of a shut down at the Blend site, Wheathampstead would also need to be shut down to prevent the unwholesome high-PFAS-concentration water from entering supply. For these reasons, the Enhanced Blending option as a stand-alone solution has been ruled out as the preferred solution.

Meeting Affinity Water's Outcomes

The requirement for this investment is to meet the commitments set out in our Strategic Direction Statement to "Deliver what our customers need, ensuring affordability for all," which encompasses "Exceed[ing] customers' expectations for drinking water," and to "Be prepared for change and resilient to shocks and stresses".

The primary performance commitment relevant to this business case is unplanned outage, as a water treatment works will be turned off and taken out of operation if the concentration of PFAS chemicals is too high for us to be able to adequately ensure we can meet water quality regulations at consumer properties.

The secondary performance commitment linked to this business case is CRI (compliance risk index). By investing in treatment solutions, we are ensuring that we are safeguarding water quality for our consumers, now and in the future, in the most cost-efficient way.

Justification of the Preferred Option

In summary, our selection of the preferred option for each site will ensure that PFAS concentrations are kept within the safe limit as per DWI guidance and will also ensure the output of the four sites across the PFAS raw water enhancement scheme does not have to be reduced due to PFAS levels.

Baldock Road and Bowring PFAS: The installation of a GAC plant on site at Bowring mid-way through AMP8, combined with an enhanced blending solution commencing at the beginning of AMP8, enables the localised reduction of the PFAS concentration in the raw water to below the safe limit. Based on the R&V and NPV studies the GAC solution is the best value option as it removes close to 100% of the risk and is not solely dependent on the operational status of Bowring and Fuller to provide the blend to dilute the PFAS concentration, although the sole reliance on blending will continue until the treatment is installed and commissioned. Additionally, latest sample data shows that the concentration detected now continually exceeds the safe limit of 0.1 µg/l. The low Opex costs associated with the Enhanced Blending solution also makes it an attractive option in combination with treatment.

Blackford PFAS: The installation of a GAC plant on site at Blackford commencing at the beginning of AMP8, enables the localised reduction of the PFAS concentration in the raw water to below the safe limit. Based on the R&V and NPV studies the GAC solution is the best value option as it removes close to 100% of the risk and is not solely dependent on the operational status of any one site borehole or other main/source to provide the blend to dilute the PFAS concentration. Additionally, while the latest sample data shows that the concentration detected is steadily decreasing over the last decade (peaks currently exceed the safe limit of 0.1 µg/l) which would normally indicate blending as more of a viable solution, note that Blackford's abstraction rates have also decreased in recent years which appears to be directly impacting PFAS concentrations in the raw water.

Holywell PFAS: The exchanging of GAC media in the existing GAC plant at the beginning of AMP8, enables the localised reduction of the PFAS concentration in the raw water to below the safe limit. Based on the R&V and NPV studies the GAC solution is the best value option, given that it removes close to 100% of the risk and is not solely dependent on the operational status of any one on-site borehole to provide the blend to dilute the PFAS concentration. Additionally, latest sample data shows that the concentration detected is gradually increasing although currently within the safe limit of 0.1 µg/l; however there have been two observed spikes above the safe limit over the last decade. The relatively low Opex costs associated with the GAC solution, alongside the significant NPV benefits which far outweighs that of the blending option, contribute to making the GAC solution an attractive option to the business.

Wheathampstead PFAS: The utilisation of the existing hexavalent chromium ion exchange plant alongside an R&D trial (PFAS-specific ion exchange pilot plant) at Wheathampstead, at the beginning of AMP8, enables the localised reduction of the PFAS concentration in the raw water to below the safe limit. Based on the R&V and NPV studies this solution is the best value option, given that it removes close to 100% of the risk and is not solely dependent on the operational status of Shakespeare Road source to provide the blend to dilute the PFAS concentration. Additionally, latest sample data shows that the detected concentration of PFOS is increasing over the last decade; average concentrations currently exceed the safe limit of 0.1 µg/l in borehole 2. Having the lowest Capex of the options and relatively low Opex costs, alongside the significant NPV benefits which far outweighs that of the blending option, the hexavalent chromium Plant and R&D trial solution is an attractive option to the business.

Delivery Considerations

Related Projects

WINEP Sustainability Reductions: This project will need to be coordinated with Blackford turbidity and manganese treatment planned as part of AMP8 Investments.

Lessons Learnt

Specific to Wheathampstead, the requirement for DWI Reg 31 approval needed for new resins led optioneering focus on resins with approval or in the process of obtaining approval.

Delivery Risk Management

Recent experience gained through delivery of GAC schemes gives more certainty over the time, costs, and specification required for these projects. Aside from this, any other project risks will be dealt with using the normal project life-cycle processes and the framework supply chain. As mentioned earlier in the business case, projects such as Wheathampstead hexavalent chromium ion exchange treatment plant and Stonecross GAC treatment plant have been used in the building-up of solution costs, which helps to mitigate the delivery risk of over-spending.

Once a project manager has been appointed to each project, they will manage the project delivery and associated risks for implementation. These will include the activities listed below which may increase as the detailed planning progresses and further risks are identified.

- Project Delivery; agreeing and monitoring of construction programme & timescales with vendors and associated supply chain management.

- Buildability: Flows meet blending requirements to reduce PFAS Levels below the ideal limit of <0.1 µg/l and still provides satisfactory pressure for our customers. PFAS plant design reduces levels to below the ideal limit of <0.1 µg/l and maintains a satisfactory level of service for our customers.

- Controls and Telemetry.

- Water Quality; ensure new solution is safe for customers prior to entering service and ensure that ongoing monitoring is in place to ensure customers are protected.

- Health & Safety; detailed assessments will be taken and highlight any additional risks such as working by railway lines.

- Roadworks; liaison with the local authority for other utility work plans in the area, obtaining permits to work and ensure resurfacing plans are completed.

- Planning permissions; obtaining required permissions for new buildings to house the PFAS plants.

Monitoring and Reporting of Benefits

The delivery of these schemes will be tracked in line with capital delivery milestones and will be monitored as a priority to ensure each achieves the deadlines set in the DWI notices and PCDs. A dedicated Treatment Board forms part of the governance monitoring, where any issues with time, cost, or quality can be escalated and resolved in a timely manner.

We will continue to monitor the concentration of PFAS compounds in the raw, part-treated, and final water at Wheathampstead WTW, to establish a baseline for the efficacy of PFAS removal, regeneration, and bed life of the ion exchange treatment. Controls will remain in place during this time to safeguard water quality.

We will install and monitor the efficacy of the ion exchange pilot plant containing PFAS-selective resin to determine whether this resin is suitable for treatment of the water at Wheathampstead, and what design parameters should be used for operation of a full-scale treatment plant.

We will monitor the efficacy of PFAS removal by different GAC media and assess if regenerated media is an option at our Holywell WTW. Controls will remain in place during this time to safeguard water quality.

Once the new solutions are in place and successfully commissioned, we will provide ongoing sampling monitoring of the water to ensure that the PFAS concentrations remain below the DWI guidance limit of <0.1µg/l.

Further detail regarding how we have ensured the deliverability of our full investment portfolio is provided within AFW 32 Deliverability of our Plans

Supporting Information

1. DWI Chief Inspector's report, 2022

Table 7.

The number of test results from raw water PFAS monitoring

Company	Total raw water tests analysed	Results below LOD	Tier 1 - <0.01 µg/l	Tier 2 - <0.1 µg/l	Tier 3 - ≥0.1 µg/l
AFW	10,652	9,999	14	566	73
ANH	121,732	116,951	4,474	285	22
BRL	2,115	1,987	113	15	0
CAM	2,822	2,807	15	0	0
ISC	799	771	21	7	0
NES	4,136	3,704	418	14	0
PRT	4,608	4,477	119	12	0
SES	366	299	66	1	0
SEW	10,976	10,610	280	86	0
SRN	12,462	11,958	406	98	0
SST	7,627	9,684	295	59	0
SVT	2,538	2,518	20	0	0
SWB	1,739	1,730	9	0	0
TMS	1,037	728	300	9	0
UUT	5,290	4,996	271	23	0
VWP	57	57	0	0	0
WSX	1,116	1,067	43	6	0
YKS	12,403	12,195	206	2	0

At Tier 2, companies are required to monitor raw and final water, and review their control measures in consultation with health authorities and the Inspectorate. The Tier 3 results at Affinity are from 5 sites which are subsequently blended, and the Tier 3 results from Anglian are from two groundwater boreholes, which are also subsequently blended.

Figure 22. From DWI Chief Inspector's report 2022, test results from raw water PFAS monitoring.

Table 8.

Number of treated water samples in Tiers 1, 2 and 3 by company

Company	Total treated water tests analysed	Results below LOD	Tier 1 - <0.01 µg/l	Tier 2 - <0.1 µg/l	Tier 3 - ≥0.1 µg/l	Tier 3 in supply
AFW	4,118	3,966	9	143	0	-
ANH	120	14	106	0	0	-
BRL	752	634	83	35	0	-
CAM	1,977	1,971	6	0	0	-
ISC	470	454	14	2	0	-
NES	4,535	3,712	774	49	0	-
SES	636	499	136	1	0	-
SRN	83,868	82,067	1,688	111	2	0
SST	6,091	3,567	190	37	0	-
SVT	376	368	8	0	0	-
SWB	2,492	2,486	6	0	0	-
UUT	2,790	2,571	199	20	0	-

Figure 23. From DWI Chief Inspector's report 2022, table showing number of treated water samples in Tiers 1, 2 and 3 by company.

2. Technology options research

Evidence from the supplies and U.S. Environmental Protection Agency (EPA) recognise GAC and ion exchange as proven treatment technology for PFAS removal. Their research and guidance documents highlight the effectiveness of both treatment processes in reducing PFAS concentrations in drinking water. We have also learnt from the experiences of other water companies who have implemented PFAS removal treatment and will draw on our own experiences with implementing GAC treatment for PFAS as part of the accelerated funding project at Holywell WTW.

EPA treatability information[15]: Evidence from the EPA treatability database suggest good PFOS removal rates (>90%) were seen with A600E resin in a study reported in Water Research in 2016 [16]. This work focused on the application of three strong anion exchange resins (Purolite® A520E, A600E and A532E) for the removal of traces of PFOA, PFOS, PFBA and PFBS concentrations from drinking water.

[15] EPA Treatability Database PFAS

[16] 'Use of Strong Anion Exchange Resins for the Removal of Perfluoroalkylated Substances from Contaminated Drinking Water in Batch and Continuous Pilot Plants' Zaggia, A., Conte, L., Falletti, L., Fant, M., and Chiorboli, A

Evidence from the study using transmission electron analysis on saturated resins showed that large molecular macro-aggregates of PFAS can form in the intraparticle pores of resin indicating that ion exchange is not the only mechanism involved in PFAS removal. Other data obtained from the experiments showed higher sorption capacity for longer chained sulphonic group compounds, which are the prevalent PFAS compounds seen at Wheathampstead.

The study also indicated that A600E removal rates decreased following regeneration and it is likely that irreversible saturation phenomena take place in A600E which cannot be resolved by the 0.5% NH4Cl and 0.5% NH4OH regenerating solution used in this study. However, the study notes that in this event an extraordinary off-site regeneration using 80% ethanol þ 1% NH4Cl, which has proven effective in restoring 100% of the PFAS removal capacity in batch experiments, could be adopted. Discussions with the manufacture on this have been inconclusive on the longer-term impacts of using the chromium (IV) resin for PFAS removal.

Our chromium (VI) resin ion exchange trial at Wheathampstead WTW ran from May to August 2021.

Resin was being regenerated approximately once per fortnight, from week commencing 29 March through to the start of August 2021.

- The last run started 4 August 2021 and breakthrough for chromium (VI) was seen around 9 August 2021. However, we left the plant running until 25 August 2021 and no PFOS breakthrough was seen in the subsequent two weeks.

- The table below shows the PFOS concentrations in the inlet (borehole 2) and outlet of the chromium (VI) ion exchange pilot plant. PFOS concentrations post treatment was less than the analytical limit of confidence.

Table 16. PFOS concentrations in the inlet (borehole 2) and outlet of the chromium (VI) ion exchange pilot plant.

Sample Date	Wheathampstead Raw 2 PFOS concentration µg/l	Wheathampstead Agua DB Pilot Plant Outlet PFOS concentration µg/l
26/05/2021	0.08	<0.014
28/05/2021	0.083	<0.014
31/05/2021	0.066	<0.014
01/06/2021	0.061	<0.014
04/06/2021	0.116	<0.014
07/06/2021	0.095	<0.014
09/06/2021	0.142	<0.014
11/06/2021	0.125	<0.014
14/06/2021	0.081	<0.014
16/06/2021	0.088	<0.014
18/06/2021	0.087	<0.014
21/06/2021	0.091	<0.014
23/06/2021	0.086	<0.014
25/06/2021	0.077	<0.014
28/06/2021	0.174	<0.014
30/06/2021	0.09	<0.014
02/07/2021	0.088	<0.014
05/07/2021	0.088	<0.014
07/07/2021	0.091	<0.014
11/07/2021	0.09	<0.014
13/07/2021	0.084	<0.014
14/07/2021	0.083	<0.014
16/07/2021	0.087	<0.014
19/07/2021	0.085	<0.014
21/07/2021	0.081	<0.014
28/07/2021	0.081	<0.014
30/07/2021	0.087	<0.014
02/08/2021	0.083	<0.014
06/08/2021	0.092	<0.014
13/08/2021	0.048	<0.014
16/08/2021	0.068	<0.014
18/08/2021	0.07	<0.014

Baldock Road/Bowring assessment of location of GAC within the treatment train:

TCE's like PFOS are organic contaminants. Evidence from a study[17] comparing PFAS removal across multiple groundwaters for eight GACs and alternative adsorbent also investigated the impact of TCEs on PFOA removal performance. They concluded that solvents like TCEs will negatively impact PFOA adsorption and corresponding time to GAC changeout at sites with VOCs co-contamination with PFAS.

[17] Comparing PFAS removal across multiple groundwaters for eight GACs and alternative adsorbent. Manmeet W. Pannu, Joseph Chang, Ricardo Medina, Scott A. Grieco, Michael Hwang, Megan H. Plumlee.

Appendix 1 – Optioneering: Supporting Business Opportunity and Risk Assessments

Baldock Road / Bowring

Affinity Water — OPPORTUNITY and RISK ASSESSMENT: SUMMARY

Notes: Click on the ? to see the Helpsheet	Units	RISK 1	RISK 2	RISK 3	RISK 4
Only populate relevant green shaded cells		Risk of PFAS WQ failure (> 0.1)	Risk of Unplanned Outage	Risk of water supply interruption or low pressure (reducing supply to Weston Hills Reservoir Storage, as a result of non-wholesome levels of PFAS > 0.1)	Risk of compromised resilience due to reliance on blend with Bowring
Mitigated OPEX ?				**£1,022**	**£2,808**
What is the annual value of any mitigated OPEX	£			1021.5	2807.99
Event Risk Index (ERI) ?		**£5,572**			
What is the ERI seriousness Score?(0-5)?	List	2RegulatoryImpact			
What is the duration of the ERI event?	Hours	168			
How many people are impacted by the ERI event?	No. of people	685			
What is the ERI Assessment Score (1-5)?	List	3RecommendationsMade			
Compliance Risk Index (CRI) ?		**£3,155**			
What is the CRI Parameter Score (1-5)?	List	5HealthRisk			
What is the CRI Assessment Score (0-5)?	List	3RecommendationsMade			
Which Location is the risk related to?	List	Baldock/Letchworth_WQZ			
C-MeX Risk/Benefit ?					**£43,594**
What is the expected Improvement/deterioration (Change) in Customer Service Score (CSS)?	Population				22500
What is the expected Improvement/deterioration (Change) in Customer Experience Score (CES)?	Population				22500
Financial, Legal and Reputational Risk (FLR) ?		**£10,571**			
Amount of penalty or fine if the risk is not mitigated?	£	10571			
Unplanned Outage (AGA related) ?			**£19**		**£3**
Which Location is the risk related to?	List		Baldock Road_Source		Baldock Road_Source
If failure occurs, what is the site production capacity reduced to?	Ml/d				
How many days would it take to get production back to peak capacity?	days		7		1
		£19,297	£19	£1,022	£46,405

Blackford

Affinity Water — OPPORTUNITY and RISK ASSESSMENT: SUMMARY

Notes: Click on the ? to see the Helpsheet	Units	RISK 1	RISK 2
Only populate relevant green shaded cells		Unplanned Outage	Water supply interruption to water supply zone WSZ047 or low pressure (as a result of non-wholesome levels of PFAS > 0.1).
Average Time Properties Experience Low Pressure ?			**£851,000**
What is the expected duration of these low-pressure events below 15m head?	Minutes		2880
How many properties are impacted by these low-pressure events?	No. of properties		5550
Event Risk Index (ERI) ?			**£12,898**
What is the ERI seriousness Score?(0-5)?	List		2RegulatoryImpact
What is the duration of the ERI event?	Hours		48
How many people are impacted by the ERI event?	No. of people		5550
What is the ERI Assessment Score (1-5)?	List		3RecommendationsMade
Compliance Risk Index (CRI) ?			**£2,601**
What is the CRI Parameter Score (1-5)?	List		5HealthRisk
What is the CRI Assessment Score (0-5)?	List		3RecommendationsMade
Which Location is the risk related to?	List		Blackford_WTW+Source
C-MeX Risk/Benefit ?			**£10,753**
What is the expected Improvement/deterioration (Change) in Customer Service Score (CSS)?	Population		5550
What is the expected Improvement/deterioration (Change) in Customer Experience Score (CES)?	Population		5550
Financial, Legal and Reputational Risk (FLR) ?			**£112**
Amount of penalty or fine if the risk is not mitigated?	£		112
Unplanned Outage (AGA related) ?		**£4,289**	
Which Location is the risk related to?	List	Blackford_WTW+Source	
If failure occurs, what is the site production capacity reduced to?	Ml/d		
How many days would it take to get production back to peak capacity?	days	365	
		£4,289	£877,363

Holywell

OPPORTUNITY and RISK ASSESSMENT: SUMMARY

Notes: Click on the ? to see the Helpsheet	Units	RISK 1	RISK 2	RISK 3
Only populate relevant green shaded cells		Risk of PFAS WQ failure (> 0.1)	Unplanned Outage	Water supply interruption or low pressure (as a result of non-wholesome levels of PFAS > 0.1).
Water Supply Interruptions (I2S) ?				**£5,340,409**
How many properties are impacted by these interruptions?	No. of properties			4680
What is the expected duration of these interruptions?	Minutes			10080
Average Time Properties Experience Low Pressure ?				**£7,883,096**
What is the expected duration of these low-pressure events below 15m head?	Minutes			10080
How many properties are impacted by these low-pressure events?	No. of properties			14689
Event Risk Index (ERI) ?		**£39,826**		**£11,379**
What is the ERI seriousness Score?(0-5)?	List	2RegulatoryImpact		2RegulatoryImpact
What is the duration of the ERI event?	Hours	168		48
How many people are impacted by the ERI event?	No. of people	4896.333333		4896.333333
What is the ERI Assessment Score (1-5)?	List	3RecommendationsMade		3RecommendationsMade
Compliance Risk Index (CRI) ?		**£4,102**		
What is the CRI Parameter Score (1-5)?	List	5HealthRisk		
What is the CRI Assessment Score (0-5)?	List	3RecommendationsMade		
Which Location is the risk related to?	List	Holywell_WTW+Source		
C-MeX Risk/Benefit ?				**£19,922**
What is the expected Improvement/deterioration (Change) in Customer Service Score (CSS)?	Population			14689
What is the expected Improvement/deterioration (Change) in Customer Experience Score (CES)?	Population			1468.9
Financial, Legal and Reputational Risk (FLR) ?		**£10,571**		**£521**
Amount of penalty or fine if the risk is not mitigated?	£	10571		521
Unplanned Outage (AGA related) ?			**£95**	
Which Location is the risk related to?	List		Holywell_WTW+Source	
If failure occurs, what is the site production capacity reduced to?	Ml/d			
How many days would it take to get production back to peak capacity?	days		7	
		£54,498	£95	£13,255,327

Wheathampstead

OPPORTUNITY and RISK ASSESSMENT: SUMMARY

Notes: Click on the ? to see the Helpsheet	Units	RISK 1	RISK 2	RISK 3	RISK 4
Only populate relevant green shaded cells		Risk of PFAS WQ failure (> 0.1)	Risk of Unplanned Outage	Risk of water supply interruption or low pressure (reducing supply to Shakespear Road Reservoir Storage, as a result of non-wholesome levels of PFAS > 0.1)	Risk of compromised resilience due to reliance on blend with Shakespeare Road.
Water Supply Interruptions (I2S) ?				**£4,400,132**	**£55,347**
How many properties are impacted by these interruptions?	No. of properties			3856	16297
What is the expected duration of these interruptions?	Minutes			10080	30
Average Time Properties Experience Low Pressure ?				**£5,467,560**	
What is the expected duration of these low-pressure events below 15m head?	Minutes			10080	
How many properties are impacted by these low-pressure events?	No. of properties			10188	
Event Risk Index (ERI) ?		**£31,364**			
What is the ERI seriousness Score?(0-5)?	List	2RegulatoryImpact			
What is the duration of the ERI event?	Hours	168			
How many people are impacted by the ERI event?	No. of people	3856			
What is the ERI Assessment Score (1-5)?	List	3RecommendationsMade			
Compliance Risk Index (CRI) ?		**£1,241**			
What is the CRI Parameter Score (1-5)?	List	5HealthRisk			
What is the CRI Assessment Score (0-5)?	List	3RecommendationsMade			
Which Location is the risk related to?	List	Wheathampstead_WTW+Source			
C-MeX Risk/Benefit ?				**£11,560**	**£31,575**
What is the expected Improvement/deterioration (Change) in Customer Service Score (CSS)?	Population			3856	16297
What is the expected Improvement/deterioration (Change) in Customer Experience Score (CES)?	Population			10188	16297
Financial, Legal and Reputational Risk (FLR) ?		**£10,571**		**£521**	
Amount of penalty or fine if the risk is not mitigated?	£	10571		521	
Unplanned Outage (AGA related) ?			**£25**		**£0**
Which Location is the risk related to?	List		Wheathampstead_WTW+Source		Wheathampstead_WTW+Source
If failure occurs, what is the site production capacity reduced to?	Ml/d				
How many days would it take to get production back to peak capacity?	days		7		0.020833333
		£43,176	£25	£9,879,773	£86,923

Appendix 2 – Optioneering: Supporting Risk and Value Assessments

Baldock Road / Bowring

Risk Index (= WLC / Risk Reduction) (Lowest value is the best option (Green) , highest is the worst option (Red))						Delete options if not required		Only populate green shaded cells
Solution Option Description	**Capex WLC**	**Opex WLC**	**WLC**	**Starting Risk Value**	**Residual Risk / Opp**	**Risk Reduction / Opp Attained**	**Risk Index**	**Notes**
Enhanced Blending with Bowring and Fuller: Existing blending enhanced with tighter control mechanism.	£43,600.40	£35,000.00	£78,600.40	£6,417,943.87	£5,455,252.29	£962,691.58	0.08	Based on efficacy of 15%.
Ion-Exchange: New PFAS-specific Ion-exchange plant, based on non-regenerable ion-exchange resin (not DWI Reg 31-approved) + purchase of additional land.	£4,966,671.37	£1,420,400.00	£6,387,071.37	£6,417,943.87	£2,406,728.95	£4,011,214.92	1.59	Based on efficacy of 63%.
Granular activated carbon (GAC): install GAC on site at Baldock Road or Bowring, with specialised PFAS removal media + purchase of additional land.	£5,321,198.00	£3,504,755.00	£8,825,953.00	£6,417,943.87	£1,925,383.16	£4,492,560.71	1.96	Based on efficacy of 70%.
Letchworth aquifer to treat PFAS pollution at source.	£1,085,800.00	£0.00	£1,085,800.00	£6,417,943.87	£6,097,046.67	£320,897.19	3.38	Based on efficacy of 5%.
Granular activated carbon (GAC): install GAC on site at Bowring to treat both Baldock Road and Bowring raw water, with specialised PFAS removal media.	£6,857,672.21	£2,906,520.00	£9,764,192.21	£6,417,943.87	£1,604,485.97	£4,813,457.90	2.03	Based on efficacy of 75%.

Blackford

Risk Index (= WLC / Risk Reduction) (Lowest value is the best option (Green) , highest is the worst option (Red))						Delete options if not required		Only populate green shaded cells
Solution Option Description	**Capex WLC**	**Opex WLC**	**WLC**	**Starting Risk Value**	**Residual Risk / Opp**	**Risk Reduction / Opp Attained**	**Risk Index**	**Notes**
Blending: Dedicated main from Blackford to Harefield Reservoir (network modelling required).	£5,428,910.68	£0.00	£5,428,910.68	£2,416,609.05	£1,691,626.33	£724,982.71	7.49	Based on efficacy of 30%.
Blending: Install flow meters and control valves in the lines from Blackford to the 12" and 30" mains to always ensure sufficient blending and dilution in both mains (network modelling required).	£95,110.80	£25,000.00	£120,110.80	£2,416,609.05	£1,691,626.33	£724,982.71	0.17	Based on efficacy of 30%.
Blending: Install blending tank and relift pumps on site (network modelling required).	£1,650,757.21	£0.00	£1,650,757.21	£2,416,609.05	£1,449,965.43	£966,643.62	1.71	Based on efficacy of 40%.
Ion-Exchange: New PFAS-specific Ion-exchange plant, based on non-regenerable ion-exchange resin (not DWI Reg 31-approved).	£11,516,011.68	£2,689,850.00	£14,205,861.68	£2,416,609.05	£483,321.81	£1,933,287.24	7.35	Based on efficacy of 80%.
Granular activated carbon (GAC): install GAC on site at Blackford, with specialised PFAS removal media.	£10,529,801.75	£3,977,770.00	£14,507,571.75	£2,416,609.05	£241,660.90	£2,174,948.14	6.67	Based on efficacy of 90%.
Letchworth aquifer to treat PFAS pollution at source.	£1,085,800.00	£0.00	£1,085,800.00	£2,416,609.05	£2,295,778.59	£120,830.45	8.99	Based on efficacy of 5%.

Holywell

Risk Index (= WLC / Risk Reduction) (Lowest value is the best option (Green) , highest is the worst option (Red))						Delete options if not required		Only populate green shaded cells
Solution Option Description	**Capex WLC**	**Opex WLC**	**WLC**	**Starting Risk Value**	**Residual Risk / Opp**	**Risk Reduction / Opp Attained**	**Risk Index**	**Notes**
Enhanced Cross-Blending of Site Boreholes: Blending enhanced with dilution control mechanism, given that there is currently no specific flow or control of the individual BHs to ensure that the correct dilution is achieved. I.e. add a control function to check that the required number of BHs with required flow are operational, installing flow meters at each blend source.	£78,029.42	£0.00	£78,029.42	£116,419,586.02	£110,598,606.72	£5,820,979.30	0.01	Based on efficacy of 5%.
Ion-Exchange: New PFAS-specific Ion-exchange plant, based on non-regenerable ion-exchange resin (not DWI Reg 31-approved).	£10,796,951.42	£2,689,850.00	£13,486,801.42	£116,419,586.02	£23,283,917.20	£93,135,668.82	0.14	Based on efficacy of 80%.
Granular activated carbon (GAC): reinstating the GAC in the existing GAC plant with virgin media recommended specifically for PFAS removal.	£511,566.00	£3,877,770.00	£4,389,336.00	£116,419,586.02	£11,641,958.60	£104,777,627.42	0.04	Based on efficacy of 90%.

Wheathampstead

Risk Index (= WLC / Risk Reduction) (Lowest value is the best option (Green) , highest is the worst option (Red))						Delete options if not required		Only populate green shaded cells
Solution Option Description	**Capex WLC**	**Opex WLC**	**WLC**	**Starting Risk Value**	**Residual Risk / Opp**	**Risk Reduction / Opp Attained**	**Risk Index**	**Notes**
Enhanced Blending with Shakespear Road: Existing blending with Shakespear Road enhanced with tighter control mechanism.	£40,155.09	£35,000.00	£75,155.09	£199,502,552.84	£184,539,861.38	£14,962,691.46	0.01	Based on efficacy of 8%.
Ion-Exchange: Chromium 6 (CrVI) Ion-exchange plant, based on CrVI regenerable ion-exchange resin.	£0.00	£2,614,850.00	£2,614,850.00	£199,502,552.84	£59,850,765.85	£139,651,786.99	0.02	Based on efficacy of 70%.
Ion-Exchange: Chromium 6 (CrVI) Ion-exchange plant, based on CrVI regenerable ion-exchange resin + R&D trial for effectivenesss of PFAS-specific resin (based on non-regenerable ion-exchange resin (not DWI Reg 31-approved).	£32,550.00	£2,614,850.00	£2,647,400.00	£199,502,552.84	£49,875,638.21	£149,626,914.63	0.02	Based on efficacy of 75%.
Ion-Exchange (AMP9): New PFAS-specific Ion-exchange plant, based on non-regenerable ion-exchange resin (not DWI Reg 31-approved).	£2,970,407.11	£1,768,550.00	£4,738,957.11	£199,502,552.84	£39,900,510.57	£159,602,042.27	0.03	Based on efficacy of 80%.
Granular activated carbon (GAC): install GAC on site at Wheathampstead, with specialised PFAS removal media.	£5,818,097.43	£1,235,447.50	£7,053,544.93	£199,502,552.84	£19,950,255.28	£179,552,297.56	0.04	Based on efficacy of 90%.

Raw Water Deterioration Programme

PFAS Ardleigh Scheme

July 2023

Contents

Summary

PFAS (Perfluoroalkyl and Polyfluoroalkyl Substances) occur in fire-fighting foams and coatings for carpets and textiles, among other uses. There are multiple PFAS compounds present in some of the groundwater aquifers from which we abstract water for supply to customers. This is usually the result of diffuse or point-source pollution events which took place in the past, although may also be related to ongoing activities.

Toxicity data is not available for many PFAS, however some PFAS, such as perfluorooctanoic acid (PFOA) and perfluorooctane sulfonic acid (PFOS) (two specific compounds included within the PFAS group), have been associated with adverse effects in animal and human studies at sufficient levels of exposure.

In January 2021 DWI (Drinking water Inspectorate) published revised guidance for the parameters PFAS and PFOA. This guidance reduced the value for wholesomeness (effectively the PCV) for PFOS from 1 µg/l to 0.1 µg/l and for PFOA from 5 µg/l to 0.1 µg/l. In July 2022 the wholesomeness value was extended to 45 other PFAS[1].

Following the DWI wholesomeness limit changes, Anglian Water carried out a review of their risk assessments including for Ardleigh WTW, an asset of shared ownership (50:50) between Anglian Water and Affinity Water. Their water quality strategy team identified Ardleigh as a site at which there was sufficient risk from PFAS compounds to merit investment at AMP8 within the PR24 portfolio for replacement of all existing GAC media with virgin media.

The requirement for this investment is to meet the commitments set out in our Strategic Direction Statement to "Deliver what our customers need, ensuring affordability for all," which encompasses "Exceed[ing] customers' expectations for drinking water," and to "Be prepared for change and resilient to shocks and stresses".

[1] DWI information letter IL_03-2022_PFAS_Guidance.pdf

Project Details

AMP8 Spend	2025-26	2026-27	2027-28	2028-29	2029-30	Total
Capex (£m)	0.32	0.33	0.00	0.00	0.00	**0.65**
Opex (£m)	0.00	0.00	0.00	0.00	0.00	**0.00**
Totex (£m)	0.32	0.33	0.00	0.00	0.00	**0.65**
Drivers						
100%	Addressing raw water quality deterioration (grey solutions)					
Benefits						
Loss of Production Capacity (Ml/d) Capex and Opex Savings (£m)						
Economic Analysis						
NPV Costs (£m) (2025-55)	**0.6**	NPV Benefits (£m) (2025-55)	**11.5**			
NPV (£m) (2025-55)	**10.9**	Benefit / Cost Ratio	**20.2**			
Six Capitals						

Natural	Social	Financial	Manufact.	Human	Intellectual
	★ ★ ★	★	★ ★		

Project Description

This business case is driven by a statutory duty to maintain potable water quality in the context of deteriorating raw water quality conditions and a change in the wholesomeness threshold limit as defined by the DWI. The investment will result in a step-change in the service level provided to consumers and is therefore Enhancement expenditure.

In this business case we describe a project which will address risk from PFAS at Ardleigh WTW as a result of high catchment risk level. The project involves replacing the existing media in all the 5 GAC contactors with virgin media for enhanced PFAS compound removal.

Project Development

Baseline Assessment

1. PFAS

As a result of their widespread use and persistence, PFAS are being found to be present in many different environments. Toxicity data is not available for many PFAS, however some PFAS, such as PFOA and PFOS, have been associated with adverse effects in animal and human studies at sufficient levels of exposure[2]. This has led to the restricted use of some of these substances in a variety of global markets.

Under section 68 of the Water Industry Act 1991 water companies have a statutory duty to supply wholesome water. Water supplies provided for human consumption (which includes cooking, drinking, food preparation and washing) and to premises where it is used for food production must meet the wholesomeness requirements of these Regulations. The Water Supply (Water Quality) Regulations 2016 regulation 4, states that water is deemed to be wholesome if it contains concentrations or values in respect of various properties, elements, organisms and substances that do not contravene the prescribed maximum, and in some cases, prescribed minimum, concentrations or value (PCV) and must not contain any micro-organism, parasite or substances at a level which could be a potential danger to human health, including where no standard has been set.

In the absence of a statutory standards for PFAS in drinking water England and Wales, the DWI have developed an approach and produced tiered guideline values[3] for water companies to adhere to. The first edition of the guidance issued in May 2007 set wholesomeness thresholds at 1.0 µg/l for PFOS and 10 µg/l for PFOA, which was revised again in October 2009 to reduce the wholesomeness threshold for PFOA to 5.0 µg/l.

In January 2021 the drinking water wholesomeness thresholds for PFOS and PFOA were both reduced again to 0.1 µg/l. This guidance from DWI was updated in July 2022 extending the guideline value of 0.1 µg/l to 45 other PFAS (IL 03/22)[4]. DWI considers that the guidance limit of 0.1 µg/l for these PFAS compounds is robust with an appropriate margin of safety to ensure the wholesomeness of drinking water.

In parallel with DWI's review of these chemicals, the European Union (EU) proposed a revision of the Drinking Water Direction (DWD[5]), the final version of which was adopted in December 2020. The revised DWD included PFAS for the first time and set an even more stringent parametric value of 0.1µg/l for the sum of 20 named PFAS, and 0.5 µg/l for total PFAS. Article 25 of the DWD outline a transitional period for

[2] DWI PFAS and Forever Chemicals
[3] Guidance on the Water Supply (Water Quality) Regulations 20161 specific to PFOS (perfluorooctane sulphonate) and PFOA (perfluorooctanoic acid) concentrations in drinking water.
[4] IL_03-2022_PFAS_Guidance.pdf
[5] Drinking Water Direction

Member States to take the measures necessary to ensure that water intended for human consumption complies with the parametric values set out in Part B of Annex I for PFAS Total and Sum of PFAS by 12 January 2026. Table 1 below shows an explanation of the EU "sum of 20 named PFAS" and "total PFAS".

Table 1. EU "sum of 20 named PFAS" and "total PFAS"

Parameter	Parametric value	Unit	Notes
PFAS Total	0,50	µg/l	'PFAS Total' means the totality of per- and polyfluoroalkyl substances. This parametric value shall only apply once technical guidelines for monitoring this parameter are developed in accordance with Article 13(7). Member States may then decide to use either one or both of the parameters 'PFAS Total' or 'Sum of PFAS'.
Sum of PFAS	0,10	µg/l	'Sum of PFAS' means the sum of per- and polyfluoroalkyl substances considered a concern as regards water intended for human consumption listed in point 3 of Part B of Annex III. This is a subset of 'PFAS Total' substances that contain a perfluoroalkyl moiety with three or more carbons (i.e. –CnF2n–, n ≥ 3) or a perfluoroalkylether moiety with two or more carbons (i.e. –CnF2nOCmF2m–, n and m ≥ 1).

PFAS Catchment Risk Assessment

The sites included in Anglian Water's proposal for virgin GAC media replacement are based on the outcome of their own PFAS catchment risk assessment process, results from Anglian Water internal monitoring programme for PFAS to date and the outputs of Anglian Water's Cranfield University research on Beck Row raw water and the removal efficacy of the existing GAC and PFAS breakthrough.

All of Anglian Water's raw water sources are assessed either through a Surface Water Risk Assessments (SWRAs) or a Catchment Risk Assessments for Groundwater Sources (CRAGs) and against defined pollution categories. These can fall into five risk categories: Very High, High, Moderate, Low and Very Low. These categories feed directly into their Water Quality Risk Portal and Regulation 28 risks at Catchment (controlled risk) and Abstraction (uncontrolled risk).

Anglian Water has determined that surface water sites are assessed as 'very high' PFAS risk due the scale of the surface water catchments, and the number of hazardous activities likely to be within them.

Anglian Water commissioned a project with Wood PLC in 2021 to further develop their PFAS risk assessment methodology to better establish the risk to each of their groundwater sources. As previously detailed, this method uses the source-pathway receptor model and was updated following IL 03/2022 to incorporate additional requirements. WSP (which includes Wood PLC) have since further developed their PFAS catchment risk assessment based upon the minimum PFAS source considerations for risk assessments detailed in IL 03/2022. This work concluded in January 2023 and has been reviewed by their Ground Water Risk Specialist, this also included a review of the PFAS sample data to date at a source level.

Anglian Water reviewed the GIS risk files from WSP, which show the location of the hazardous activities they have identified within the catchment. The outputs of Anglian Water's SWRA and CRAGS is used to inform their Regulation 28 risk reports, summarised in Table 2 below.

Table 2. Anglian Water's SWRA and CRAGS RAG

CRAGS/SWRAS score	Likelihood	Impact	Total score	RAG
Very high	365	3400	1241000	R
High	52	3400	176800	R
Moderate	4.55	3400	15470	A
Low	0.1	3400	340	G
Very low	0.02	3400	68	G

Anglian Water used available internal monitoring sample data above Limit Of Detection (LOD)/Limit Of Quantification (LOQ) for the last 5 years to ensure the initial risk categories aligned with any appropriate sample data. This will predominately be for PFOS and PFOA, as Anglian Water sampling for the full 47 compounds only started recently. As they obtain further raw water sample data from their ongoing sampling programme the PFAS catchment risk assessments will continue to be validated on an annual basis as a minimum, in line with their catchment risk assessment process.

The Anglian Water full suite of PFAS sampling is in its infancy stages and they are building up sample data through their internal monitoring programme to understand the PFAS risks in the catchment. Due to the limited time that they have been sampling for the 47 compounds, they have a significant data gap in their knowledge on any effects of seasonality, hydrological conditions in terms of precipitation and surface or groundwater flows, pumping regime and any other relevant factors which could be applicable. They do have evidence that Beck Row source does show seasonality with a number of PFAS compounds present in the source.

Some of Anglian Water's surface WTW have already triggered tier 2 (i.e. PFAS compounds detected >0.01 µg/l (>10 ng/l)) on the raw and final water, this includes Ardleigh WTW. So, along with the risks identified in the risk assessment process it has been included in the investment for virgin GAC replacement.

Anglian Water sampling strategy for the full 47 PFAS compounds started in September 2022. Prior to this date all high priority raw waters (which was those assigned as a very high categorisation for their PFAS catchment risk) were sampled as part of the priority sampling in November 2021 in line with IL 05/2021. The sources with a high-risk catchment risk assessment were sampled in 2022 for a wider PFAS suite. They have since developed in-house laboratory methodology for analysis of the full 47 suite aligned to IL 05/2022.

The sampling frequency is determined based on the risk category of the source. Sources are categorised as very low to very high risk and are aligned to the CRAGS process. For high and very high raw water sources the sampling frequency is 12 per year. Moderate, low and very low are sampled 4 times per year. Final waters that are tier 2 or have the potential to reach tier 2 based on the sample data or risk assessment, are sampled 12 times per year and low risk 4 times a year. Following any tier 2 or tier 3 trigger on a raw or final water the sampling frequency is reviewed and enhanced further where necessary.

PFAS has recently been added to the Anglian Water GAC risk assessment sampling suite. All GAC filters are sampled twice a year to support their policy on the regeneration frequency. By including all 47 PFAS compounds to the suite of analysis, this will give them detailed information of which PFAS compounds are starting to break through the oldest GAC. This will inform their future regeneration frequency, (the current regeneration programme is based upon pesticide risk).

Evidence of sample data for all the raw and finals waters included in this proposal are provided below in part 2, section 3.

2. Ardleigh WTW

Table 3 below is colour coded to show the sample results at Ardleigh WTW either below 5 ng/l, between 5 and 10 ng/l, between 10 and 100 ng/l or over 100 ng/l per PFAS compound on the final water.

Table 3. PFAS sample results at Ardleigh WTW

WTW	3:3 FTCA	6:2 Cl-PFESA	6:2 FTS	7:3 FTCA	8:2 FTS	EtFOSE	FOSA	PFBA	PFBS	PFDoA	PFHpA	PFHXA	PFHxS	PFNS	PFOA	PFOS	PFPeA	PFPeS
Ardleigh[1]																		

Key
- Sample results below 5 ng/l
- Sample results between 5 ng/l and 10 ng/l
- Sample results between 10 ng/l and 100 ng/l
- Sample results over 100 ng/l

Drought conditions may have some potential impact on the data results for the last 8 to 10 months, due to river flow levels and Hands Of Flow abstraction licence restrictions. This has resulted in lower fill curves then we could typically see at a number of Anglian Water's reservoirs. This is an important factor in understanding the risks where drought conditions, differing pumping regimes, can have on the seasonality of the sample results.

Ardleigh WTW **raw water** all PFAS compound sample results above the LOQ from 5th November 2021 to 1st March 2023 are presented in Figure 1. below. Currently PFOS and PFHxS have exceeded 10 ng/l.

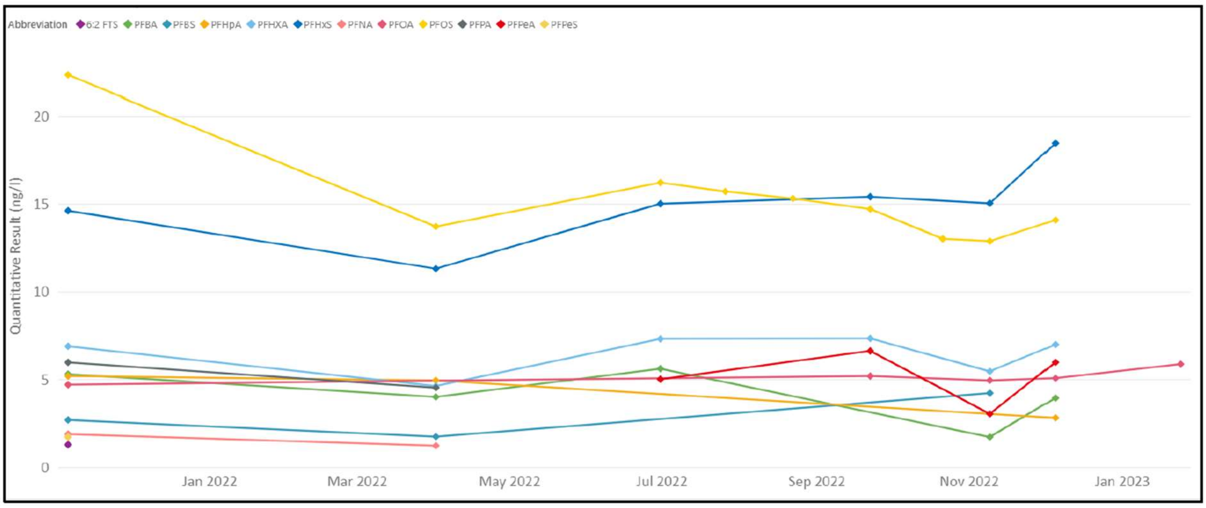

Figure 1. Ardleigh WTW raw water all PFAS compound sample results above the LOQ from 5th November 2021 to 1st March 2023

Ardleigh WTW **final water**, all PFAS compound sample results above the LOQ from 9th December 2021 to 1st March 2023 are presented in Figure 2. below. 8 Compounds were detected above the LOQ, currently both PFOS and PFHxS have had results above 10 ng/l.

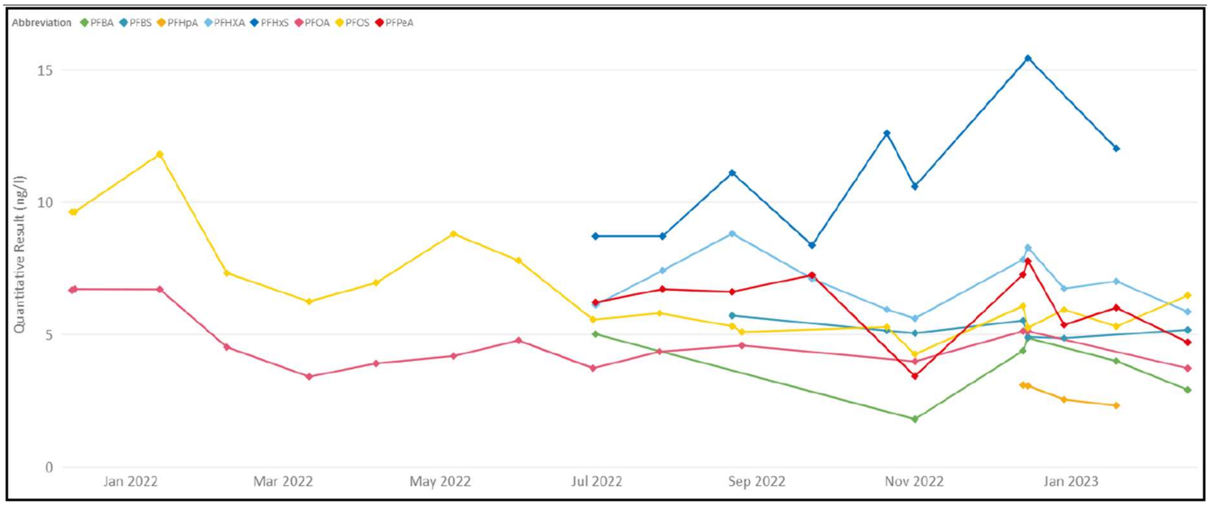

Figure 2. Ardleigh WTW final water, all PFAS compound sample results above the LOQ from 9th December 2021 to 1st March 2023

Figure 3 below shows **PFHxS** for both Ardleigh Raw (W01RAW2CD) and Ardleigh Final (W01FIN5CD) Water from 1st May 2021 to 1st March 2023.

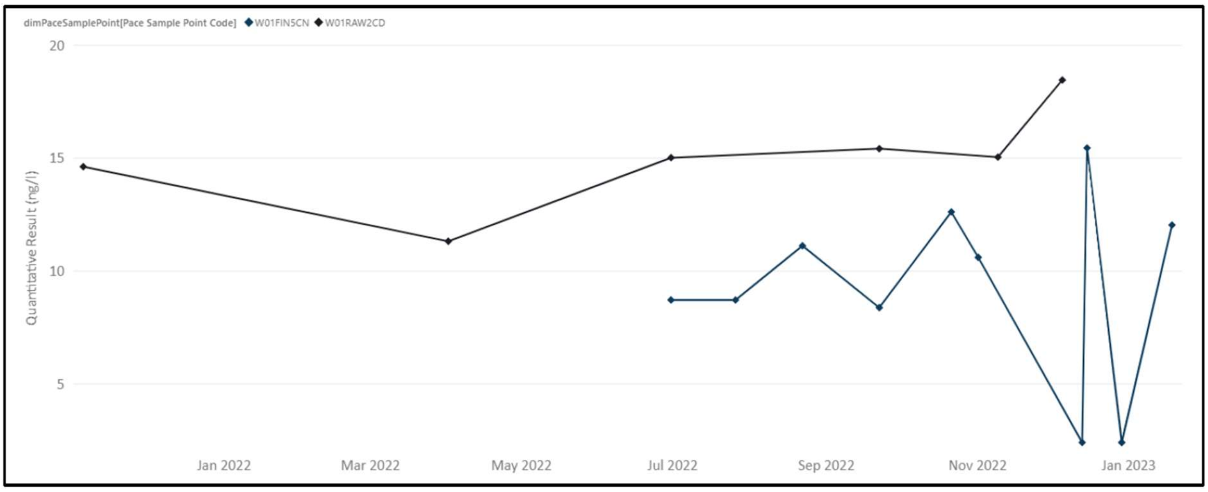

Figure 3. PFHxS for both Ardleigh Raw (W01RAW2CD) and Ardleigh Final (W01FIN5CD) Water from 1st May 2021 to 1st March 2023.

Figure 4 below shows **PFOS** for both Ardleigh Raw (W01RAW2CD) and Ardleigh Final (W01FIN5CD) Water from 1st May 2021 to 1st March 2023.

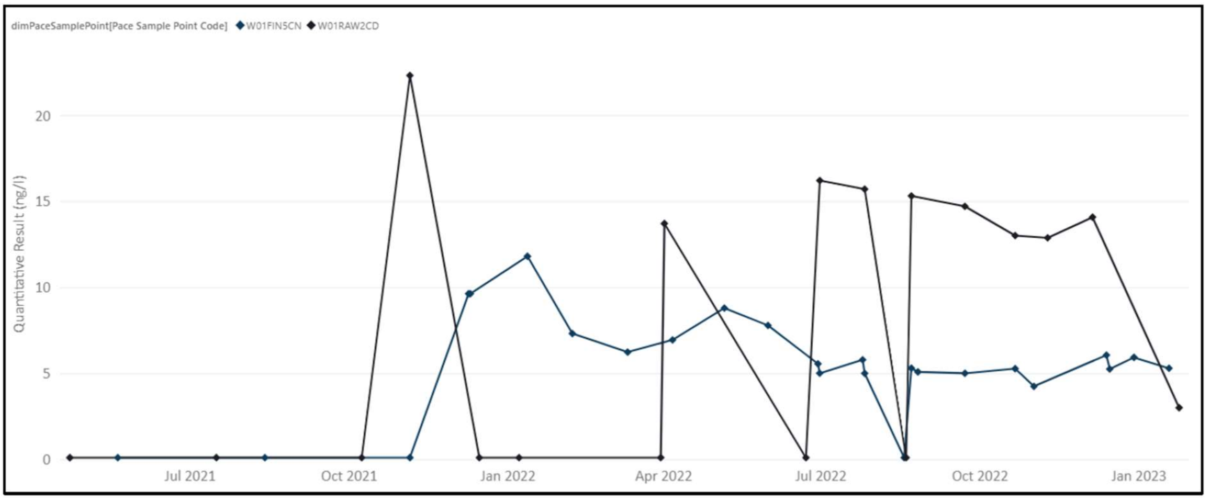

Figure 4. PFOS for both Ardleigh Raw (W01RAW2CD) and Ardleigh Final (W01FIN5CD) Water from 1st May 2021 to 1st March 2023

As detailed in their Surface Water Risk Assessments, Anglian Water assess PFAS to be a very high-risk hazard for all of their surface works due to the due to the nature of their large catchments and the number of potential contamination sources.

Table 4 below shows the risk category for Ardleigh as displayed in Anglian Water's Water Quality Risk Portal. The risk portal score is a combination of the Surface Water Risk Assessments score for the source combined with sample data, event data and operational risk at the abstraction and treatment stages. The Regulation 28 risk assessments for these assets were sent to the DWI by 21 March 2023.

Table 4. risk category for Ardleigh as displayed in Anglian Water's Water Quality Risk Portal

WTW	Catchment	Catchment Risk category	Catchment Risk score	WTW Risk category	WTW Risk score
Ardleigh	Ardleigh Reservoir	Red	1,241,000	Amber	6,766

Problem Statement and Stated Need / Driver

Some PFAS have been identified as being persistent, bio-accumulative in the environment and potentially toxic in terms of human health. The significant reduction in the wholesomeness thresholds led Anglian Water to re-evaluate the risk assessment for Ardleigh WTW on behalf of both companies as Ardleigh is a shared asset (50:50). They identified that investment was required to ensure water supplies remain wholesome and to safeguard security of supply and service levels to customers.

Risks, Issues and Requirements

Regulatory Position for PFAS in Drinking Water

In January 2021, DWI reissued their guidance in response to more data having become available on the toxicity of PFOS and PFOA. In this guidance the drinking water wholesomeness threshold for both PFOS and PFOA was amended down to **0.1 µg/l (previously 1.0 and 5.0 µg/l respectively).** The DWI also outlined its expectation that water companies adopt a three-tiered approach to the monitoring and management of PFAS in drinking water supplies, as set out in Table 5 below.

Table 5. DWI three-tiered approach

Tier	Tier Trigger Level
Tier 1: Regulation 27 – Risk assessment	<0.01 µg/l (<10 ng/l)
Tier 2: Regulation 10 – Sampling: further provisions	0.01 - 0.1 µg/l (10-100 ng/l)
Tier 3: Regulation 4(2) wholesomeness – concentrations that may constitute a potential danger to human health	>0.1µg/L (>100 ng/l)

Risks

There is currently no risk of prosecution or failing current regulatory standards as Anglian Water has implemented a comprehensive, risk-based sampling and monitoring programme on behalf of both companies. The frequency of monitoring on each source is determined by the individual risk level. This ensures that they have visibility of changes in raw water quality, and the teams monitor the trends on the water sources to identify any change in risk level.

The risk, therefore, is to water supply and water availablity. If Ardleigh were to be turned off due to increasing PFAS concentrations then likely there would be a decrease in water availability in the area. This in turn could lead to low pressure events or, in the extreme, loss of supply to customers.

As more research and health data become available there is a risk that the drinking water wholesomeness threshold for PFAS could be reduced further. The EU has a more stringent parametric value of 0.1 µg/l for the sum of 20 named PFAS, which could be adopted in the UK in the future; the proposed solutions at Ardleigh would mitigate this risk.

In March 2023 the EPA (United States Environmental Protection Agency) proposed to establish legally enforceable levels for six PFAS known to occur in drinking water[6] (summarised in the table below). The concentrations being proposed would require a further step change if adopted by the DWI.

Table 6. EPA proposed regulatory changes.

EPA is proposing a National Primary Drinking Water Regulation (NPDWR) to establish legally enforceable levels, called Maximum Contaminant Levels (MCLs), for six PFAS in drinking water. PFOA and PFOS as individual contaminants, and PFHxS, PFNA, PFBS, and HFPO-DA (commonly referred to as GenX Chemicals) as a PFAS mixture. EPA is also proposing health-based, non-enforceable Maximum Contaminant Level Goals (MCLGs) for these six PFAS.

Compound	Proposed MCLG	Proposed MCL (enforceable levels)
PFOA	Zero	4.0 parts per trillion (also expressed as ng/L)
PFOS	Zero	4.0 ppt
PFNA	1.0 (unitless) Hazard Index	1.0 (unitless) Hazard Index
PFHxS		
PFBS		
HFPO-DA (commonly referred to as GenX Chemicals)		

The proposed rule would also require public water systems to:

Currently, the DWI considers that the guidance limit of 0.1 µg/l for PFAS compounds is robust with an appropriate margin of safety to ensure the wholesomeness of

[6] Per and Polyfluoroalkyl Substances PFAS US EPA

drinking water. So, the treatment option solution we have considered is adaptive and a precautionary approach to PFAS for AMP 8.

Allocation of Costs

The delivery of this scheme is driven by a statutory requirement to maintain potable water quality in the context of deteriorating raw water quality conditions and a change in the wholesomeness threshold limit as defined by the DWI. The investment will result in a step-change in the service level provided to consumers and is therefore Enhancement expenditure.

Ardleigh WTW is jointly owned by Affinity Water (AfW) and Anglian Water (AW) on a 50:50 basis. Through formal agreement, the works is managed on a day-to-day basis Anglian Water teams due to their closer proximity. The operations and asset planning associated with the works is governed by the Ardleigh Reservoir Committee (ARC).

The ARC is co-chaired on an alternating basis by senior representation of both companies, as well as appointed Engineers from each company to support decision making and investment planning. The ARC meets quarterly to review performance and agree action plans.

This proposal is being led by the Anglian Water team, supported by the ARC, and the funding application is apportioned 50:50.

The investment does not overlap with expenditure from previous AMPs, under either Base or Enhancement. There is no overlap with other activities to be delivered through Base in the future.

DPC

This scheme is not suitable to be considered for a Direct Procurement for Customers approach as the value is significantly below the £200m TOTEX threshold.

Research, Pilots, and Technology Development

The Anglian Water GAC regeneration frequency is currently based on pesticide risk, it is not currently based upon PFAS risk with the exception of Beck Row. Anglian Water undertook innovation trials in 2006 on the efficacy of the GAC media at removing PFOS. That research concluded the carbon was effective at PFOS removal. Based on this research, the filters at Beck Row have historically been regenerated every 2 years due to the PFOS risk.

The recent PFAS guidance and requirement to sample for the 47 compounds increases Anglian Water's understanding of the number of PFAS compounds present in the Beck Row borehole. It also informs their understanding of PFAS risk at their other sites, with existing treatment which will reduce PFAS levels. With that knowledge they commissioned research with Cranfield University to undertake a project on the efficacy of the regenerated carbon testing with Beck Row raw water and carbon, comparing newly regenerated and the oldest GAC media from the site.

The Cranfield research on Rapid Small Scale Column Tests on Beck Row raw water was undertaken with the aim of observing when breakthrough occurs of the smaller chain PFAS compounds from the F400 media installed at the site. The key deliverable was to evaluate the level of PFAS removal with the type of GAC used at Beck Row WTW using bench scale testing. A final report was anticipated end of March 2023 but has not been shared with Affinity Water. The research was intended to inform Anglian Water's medium to longer term strategy for frequency of carbon regeneration. Further detail on the output of this research is provided below.

The experimental work was based on the use of Rapid Small- Scale Column Tests (RSSCTs). Water from Beck Row WTW was sent to Cranfield for testing. Eight GAC columns were operated in parallel under different operating conditions of Empty Bed Contact Time and media age (freshly regenerated and used) with duplicates. Samples were collected daily for PFAS analysis (for the full 47 suite) to understand PFAS adsorption. EBCT of 15, 35 and 60 minutes was used, 60 minutes representing the best-case scenario of flow conditions through the Beck Row plant and an EBCT of 35 minutes with the Beck Row operational borehole at its maximum flow rate. 60 minutes is unique to the Beck Row site on very reduced flow conditions.

Two samples of GAC were used in the columns, GAC that was in use at the WTW and was close to its regeneration time (circa 23 months old), and GAC that had been newly regenerated and had just been put back into service at the works.

The older GAC had an Iodine Number of 422 mg/g and a Non-Aqueous Volatile Matter Content of 13.6 %, the newly regenerated GAC had an Iodine Number of 657 mg/g, and a Non-Aqueous Volatile Matter Content of 10.8 %. For comparison virgin GAC has an iodine number of 1000-1050 mg/g, this is important as its significantly increased thus providing far better adsorption capacity compared to regenerated carbon, clearly this iodine number will decline over time as the carbon adsorption sites become full. This is controlled by regeneration. The preliminary findings were shown for the best- and worst-case scenarios, the best-case is with newly generated carbon and for the longest EBCT of 60 minutes. The worst-case is with the carbon which was due next for regeneration and with the shortest EBCT of 15 minutes. Data is presented below. The graphs of C/C0 are shown versus Cumulative Bed Volumes passed. At C/C0 = 1, breakthrough has occurred where the influent concentration and effluent concentration are the same.

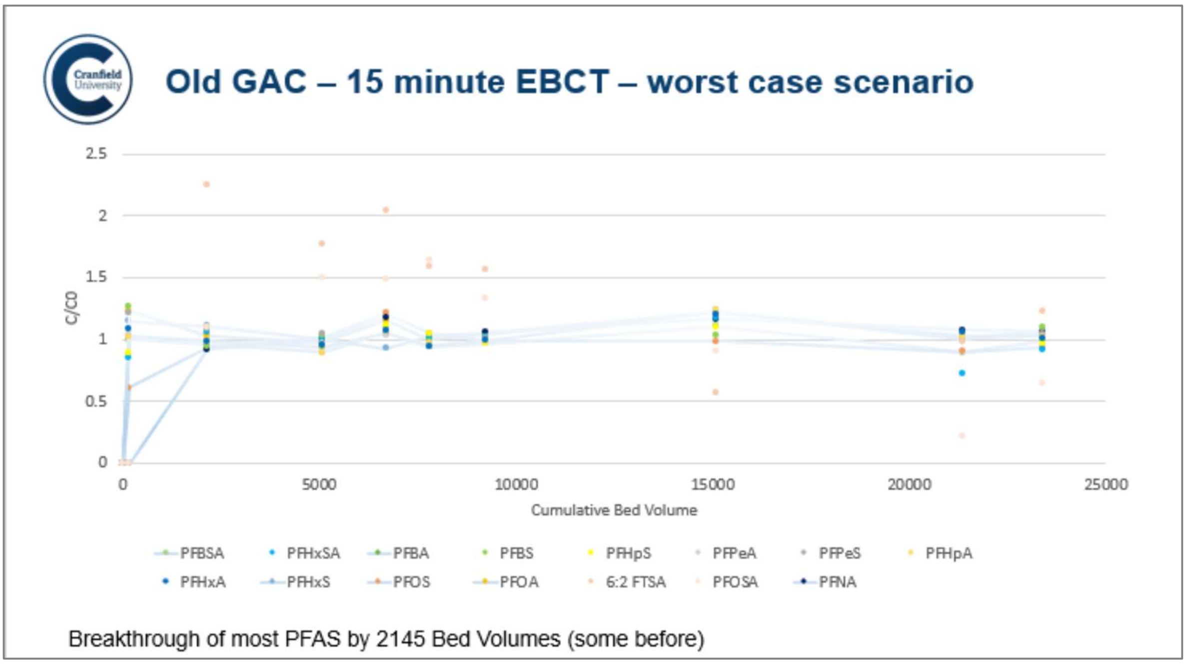

Figure 5. Old GAC – 15-minute EBCT – worst case scenario

This means breakthrough occurs at 22 days.

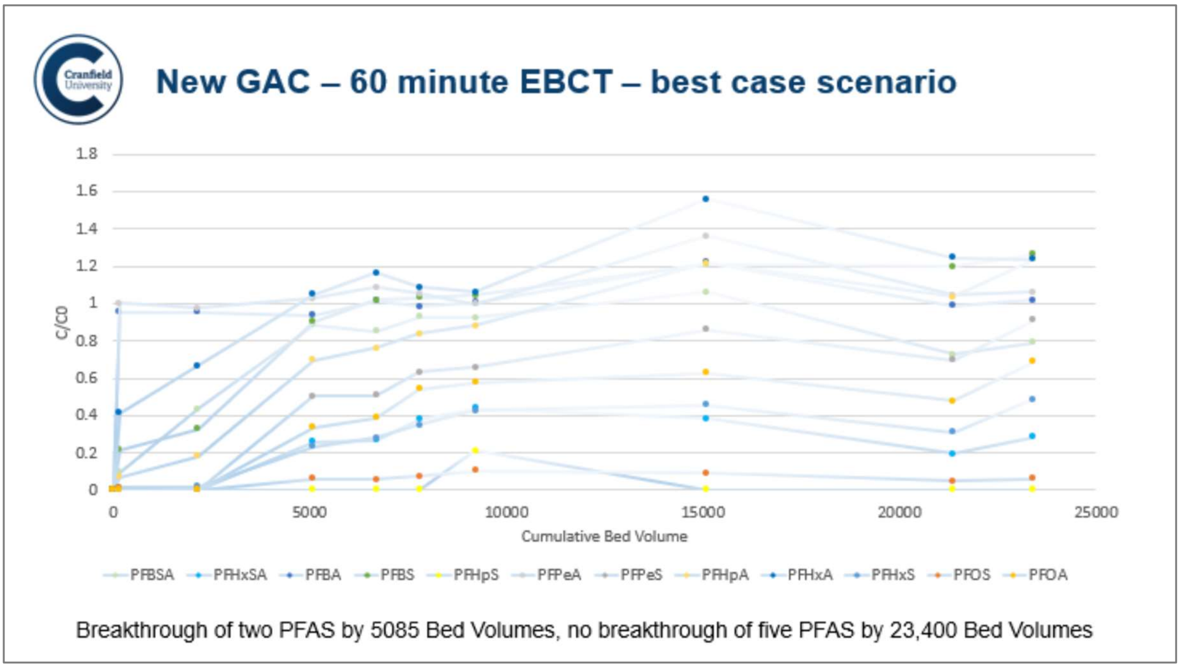

Figure 6. New GAC – 60-minute EBCT – best case scenario

This means breakthrough occurs at 211 days, (6 months). Looking at the fact that no breakthrough of 5 PFAS was found by 23,400 bed volumes, this equates to 975 days (2.67 years).

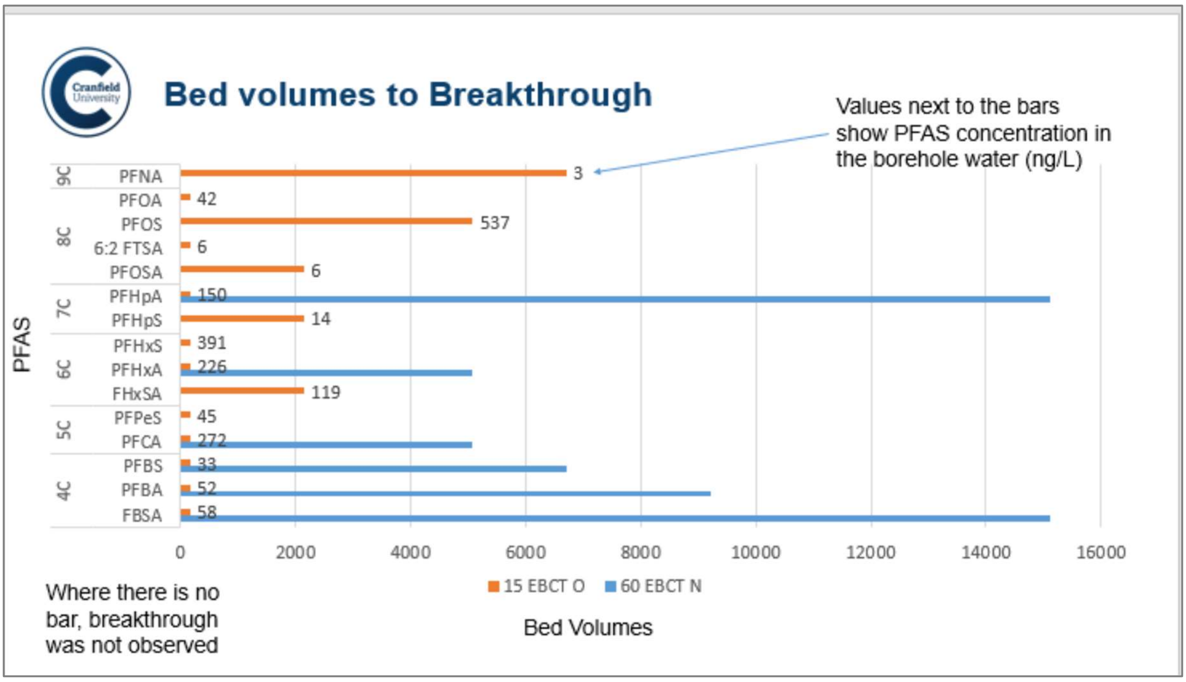

Figure 7. Bed volumes to Breakthrough

The graph above represents that data for breakthrough observed at 15- and 60-minute EBCT. The summary of the findings was as follows:

- Removal is better at longer contact times and with newly regenerated carbon.
- Removal is dependent on structure of the PFAS compound (number of carbons and chain length) as well as functionality; and
- Bedding in time still being established.
- Even with newly regenerated carbon at longer EBCTs, breakthrough of some PFAS occurs within 5,085 bed volumes namely: PFHxA (perfluorohexanoic acid) and PFPeA (perfluoropentanoic acid).

All of this data and information was used to develop the PFAS management strategy for Ardleigh WTW.

Customer Engagement

Detail of Customer Engagement work

We have undertaken extensive engagement with our customers to build a detailed understanding of their priorities and reflected these in this business case. For more detail on our customer engagement see AFW04 What Customers and Stakeholders Want.

We carried out some customer engagement,[7,8,9,10] as part of the Strategic Resource Options programme of work, looking at how customers preferred to be communicated with. This gave us the opportunity to gain some insights into their thoughts and preferences about several of the long-term plans related to water resourcing, including source types.

An evidence review was carried out of 50 documents and stakeholder interviews with each of the water companies, with documents gathered directly from the 6 water companies involved in WRSE, and the evidence was then synthesised to identify consistent findings which were triangulated to assess their strength. During the qualitative phase we tested these findings with 96 household customers across the 6 companies, including Gen Z and vulnerable customer. During the quantitative phase we held 15-minute online surveys with 1,762 household and 198 non-household customers for robust segmentation and validation of findings.

This research reinforced our understanding that water is a low salience topic with our customers, in that they have a low level of awareness and understanding of issues relating to it. This in part is driven by general satisfaction with the customer experience of water in terms of taste, smell and hardness.

We followed this up with some deep dive sessions in July 2022 to specifically test on our own long-term plans with a wide cross section of our customer base[11]. 82 customers and 10 business representatives participated in this research. Customers were divided into 'household', 'vulnerable' and 'future' groups to reflect a range of views, whilst local business representatives provided views on behalf of their place of work ('Non-household').

The Non-household individuals were recruited from businesses which are heavy water users. Customer groups covered a range of ages, socio-economic backgrounds and areas within Affinity Water's region in order to enable a diverse range of views. Given the long-term focus of the research, future customers were also included to gauge an understanding of priorities from individuals who are likely to become Affinity Water customers in the future.

[7] WRSE Customer Preferences Part A Evidence Review Final Report eftec ICS February 2021.pdf
[8] Water Club - Changes of Source - June 2022.pdf
[9] Affinity Water Customer Valuation Research Summary Report May 2023.pdf
[10] Affinity Water Customer Priorities for Long-term Ambitions
[11] 'Customer Priorities for long-term ambitions to support PR24 and long-term delivery strategies,' September 2022

Ten online focus groups were held (household and future customers) and fifteen one-to-one interviews conducted (vulnerable and non-household customers). Focus groups were conducted via online video, using the specialist VisionsLive platform, each session lasting 90 minutes. Voting exercises and activities were used throughout the focus groups, to aid engagement, capture strength of feeling, and focus the discussion on the core research questions.

These were qualitative sessions, and the outcomes gave us some insight into customer views of the relative importance to them of, among other considerations:

- Reducing amount of chemicals used in water treatment,
- Reducing carbon emissions associated with treating water for customers,
- Hardness level of their water supply, and
- Keeping customer bills as low as possible.

Finally, we held some quantitative research sessions between February and March of 2023 with a second set of workshops looking at Customer views on priorities covering customer preferences for changing service levels. Customers were generally observed to be more sensitive to avoiding deteriorated service levels compared to the preference for improvements. In general, there was a limited preference for changes in service levels for hard water and hosepipes bans.

911 household customers completed the survey between February and March 2023 800 respondents completed an online survey and 111 completed an in-person interview, qualifying as "digitally disengaged." 42% of the household respondents (383 people) were classified as being in vulnerable circumstances. Around 13% of respondents who took part in the study (117 people) were registered with the Priority Services Register. Of these 117 respondents, 31% were medically dependent on water, 56% suffered from physical issues, and 9% need information in alternative formats.

There was a good distribution among the respondents of all targeted characteristics. Females were slightly over-represented (57% of respondents) and were within +/- 7 percentage of sample quotas. Socio-economic group (SEG) profile were within +/- 3 percentage points of sample quota. All age cohorts were within +/- 4 percentage points of sample quotas.

150 non-household (NHH) respondents completed the survey online. These comprised a good mix of NHHs achieved when measured by both number of sites and by number of employees. Around a third of organisations had only 1 site (34%), 12% of respondents were a sole trader and 15% of respondents had between 100-150 employees. Also, the sample distribution by economic sector has the expected profile with 1% as Primary, 28% as Secondary and 71% as Tertiary.

Evidence of Customer Preferences

We have developed all this research and analysis into a document called 'What our Customers & Stakeholders Want[12]' which presents the findings from the various customer engagement activities. The key takeaway point from the research is that customers have a high level of inherent trust in us as a water provider, and generally are happy for us to make decisions about technology selection and water quality risk management without consultation with them – we are the experts, and they trust us to make those decisions.

Another outcome of the research was a strong steer that customers expect us to meet our regulatory duties at all times, with respect to the Water Supply (Water Quality) Regulations. Any strategic decisions we make with respect to cost or carbon emission reduction must not have any detrimental impact on water quality performance.

The outcomes from the deep-dive qualitative sessions with our own customers indicated that they have wide ranging responses to the questions of whether we should be reducing chemical use in water treatment and whether we should be reducing operational carbon emissions, which could be influenced by many factors including the respondents' own socio-economic group, with no overall preference or point-of-view expressed[13]. Two thirds of customers did not support investment to soften hard water, with a third supporting investment. Hard water tends to polarise customer opinions. However, there was a clear steer from customers, from these qualitative sessions, that their main priority over any of the other considerations was to keep bills as low as practicable.

The SRO customer communication preferences work indicated that there are some acceptance barriers in place for customers around some of our water resourcing ideas, particularly with respect to direct or indirect wastewater effluent reuse schemes. They indicated that they would need reassurance if this type of approach were taken that water would be safe to drink.

The qualitative research sessions indicated that customers were generally observed to be more sensitive to avoiding deteriorated service levels compared to the preference for improvements. Household customer values for improved service levels for areas including tap water aesthetics was relatively modest – but nevertheless improvement in these areas was viewed as beneficial. In general, there was a limited preference for changes in service levels for hard water and hosepipes bans. Respondents felt that Affinity Water's services are good value for money and were generally satisfied with the services they receive.

Customer protection

Customers will be protected by the requirements of the Price Control Deliverables (PCDs), and we also expect a DWI Notice covering the site to be issued shortly after

[12] What our Customers and Stakeholders Want V5 final.pdf
[13] Line of sight V3.docx

August 2023 which will set out the number of GAC contactors in which media must be replaced by certain dates.

Partnering

Collaboration and Partnering

Engagement with Stakeholders and Partners

- DEFRA (Department for Environment Food and Rural Affairs)

Accelerated Infrastructure Programme (AIP) Opportunity – In October 2022, Defra asked water companies to propose schemes for accelerated additional infrastructure delivery in 2023-24 and 2024-25 that would provide benefits for customers, communities, and the environment. We proposed the completion of six GAC contactors for media exchange at Holywell WTWs during Year 4 and 5 of AMP7 and submitted our draft business case to the DWI. In April 2023, Ofwat's draft decision supported the acceleration of the scheme.

- Drinking Water Inspectorate (DWI)

We were invited by the DWI to carry out some early engagement with representatives from the regulator through the Autumn of 2022. We met with them during November 2022 and shared an early view of what is likely to be included in the water quality programme for PR24 and the AIP schemes, their initial feedback was supportive of our proposals.

In January 2023 we submitted a summary statement to the DWI which highlights significant new future risk mitigation measures that we will be seeking support for in the PR24 proposals. The purpose of this statement is to:

  - to understand the justification and evidence for proposals
  - to estimate the number and type of submissions to expect

In addition to the summary paper, in March 2023 we submitted to DWI our draft business cases for drinking water quality investments.

- Environment Agency (EA)

We have liaised closely with the EA to develop our WINEP and catchment management plans for PR24, and have taken a holistic approach at an Operational Catchment scale, incorporating:

  - Sustainability reductions (SR's)
  - Abstraction Impact Assessments
  - Biodiversity enhancement
  - Catchment and Nature-based solutions (C&NBS)
    - Revitalising Chalk Rivers - River restoration, habitat enhancement and monitoring
    - Resilient Chalk Catchments - Catchment management measures for multiple benefits (water resources, water quality, biodiversity, carbon, chalk stream resilience)
- Flagship Chalk Stream Catchment Restoration projects (CaBA strategy)

The engagement process is outlined in the schematic (Figure 8) below.

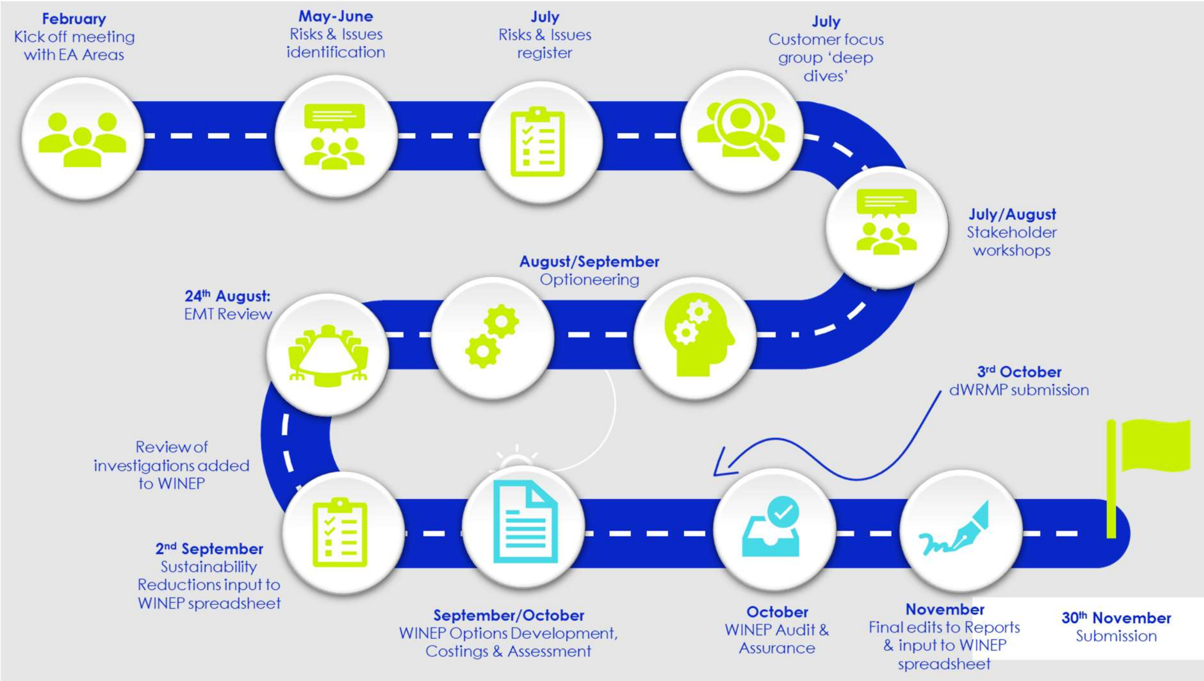

Figure 8. Schematic of our engagement process.

Co-design and Co-delivery

- Inter-company project development

While Ardleigh WTW is managed on a day-to-day basis by Anglian Water teams, by a management agreement, the operations and asset planning associated with the works is governed by the Ardleigh Reservoir Committee (ARC).

The ARC is co-chaired on an alternating basis by senior representation of both companies, as well as appointed Engineers from each company to support decision making and investment planning. The ARC meets quarterly to review performance and agree action plans.

The specific investments identified in this business case were discussed initially between the Strategic Asset Manager for Water Quality and Treatment (AfW) and the Water Quality Policy and Strategy Manager (AW), with both companies submitting applications to DWI for support of the investment which have been positively received. The value of the investment was developed by AW based on historic costs for GAC purchase and installation.

- Inter-company collaboration on PFAS

We are members of multiple inter-company groups in which we discuss significant emerging risks and potential solutions to or approaches for dealing with them. These include: Water UK (and all the sub-groups therein), UKWIR, WRc (including Disinfection Forum), Cranfield University (including UK Water Network on Potable

Water Treatment and Supply), Isle Technologies (Technology Advisory Group, Water Treatment Technical Working Group and Water Distribution Technical Working Group).

- Early engagement with technology suppliers

We have engaged early with suppliers of specialist treatment equipment in order to understand the options currently available on the market, as well as those at various stages of development currently in use in other countries (which may not hold the approvals necessary for use in the UK). We also use information from the suppliers to begin to build up cost estimates for implementation of the novel technologies, for which we do not hold any normalised cost models.

Strategy Development

All of our enhancement cases have been developed as part of our integrated investment portfolio that takes the first steps of our Long Term Delivery Strategy and achieving our ambitions as laid out in AFW03 Strategic Direction Statement.

Long-term Delivery Strategy Alignment

In our Strategic Direction Statement[14] we commit to "Deliver what our customers need, ensuring affordability for all" which encompasses "Exceed[ing] customers' expectations for drinking water." We know that customers hold inherent trust in us to make the appropriate interventions to safeguard their water quality.

There is an additional commitment to "Be prepared for change and resilient to shocks and stresses" within which we commit to "Ensure a resilient supply of water for Affinity Water customers." We are delivering on this commit in this case by providing treatment where no blending or other management of the risk is possible without detrimental effect on the resilience of our supply network in this area.

Our long-term delivery strategy related to water treatment includes an investment line covering "Addressing raw water deterioration." In this instance, there is both a deteriorating (increasing) trend in the concentration of the contaminants in the raw water and newly introduced wholesomeness threshold limits set by the DWI which, in combination, result in a high likelihood that we will need to cease use of these sources for supply within AMP8.

The investments proposed within this business case are aligned with the Core Adaptive Pathway of our LTDS and will not adversely impact any of the potential Alternate Pathways identified within the LTDS. The investments will still be required under all common reference future scenarios.

Treatment Strategy

Currently, our Treatment Strategy requires provision of treatment only when necessary due to raw water quality and when it is the best value holistic solution to provide treatment rather than any other solution.

We are exploring options around selection of treatment processes that have high power demand in preference to processes that require high chemical input in order to reduce our overall operational carbon emissions. The speed at which we implement this strategy will depend on the glidepath to net zero operational carbon emissions set by the Company, and whether these proactive changes towards

[14] AW0031_Strategic-direction-statement.pdf

power-intensive processes away from chemical-intensive processes are necessary to achieve those target future carbon emission profiles.

Adaptive Strategy

Depending on the speed at which we want to reduce our operational carbon emissions on our treatment works, it may be necessary to select a high-power demand process for treatment of PFAS over a high chemical demand process. These operational carbon emissions glide paths will become available to us shortly but are not available right now. For now, we will select best value solution based on cost and risk reduction.

This project is no regrets because we require the water from Ardleigh WTW in order to meet our supply demand balance and, without the replacement of the GAC media on the site, there is a risk that PFAS breakthrough could occur into the final water and the site may need to be turned off in AMP8. Additionally, the trend for regulation of these compounds is to reduce the allowed concentration (other countries globally have lower permitted limits) as there is deemed to be no safe concentration with respect to human health. Therefore, there is low likelihood that these regulatory limits will be raised again in the medium- to long-term.

Optioneering

We have consistently proposed best value solutions using rigorous optioneering. For more detail on our approach is provided within AFW08 Our Investment Development Process.

The optioneering and solution development for this business case has been carried out by Anglian Water on behalf of both companies. They considered blending only briefly as a solution as there are no other sources available near the site to blend with. As GAC vessels are already in place at Ardleigh WTW, the only treatment option considered by Anglian Water was replacement of the used GAC media in their existing vessels with virgin media.

This approach is in agreement with the GWI (Global Water Intelligence)-sourced maturity matrix which shows the various forms of PFAS treatment in the PFAS technology market (aside from blending) and their associated maturity levels.

The scheme in this business case has been developed after due consideration of the catchment management activities ongoing and planned for this catchment. Analysis of recent water quality data has determined that catchment management activity on its own is not sufficient to mitigate the risk, and that further intervention is needed.

Selected Options

Do Nothing, Option 0

The 'Do Nothing' option for Ardleigh WTW involves continuing to sample and monitor the raw water, triggering the site to be turned off if or when the wholesomeness thresholds are exceeded. The current control measure under the direct control of Anglian Water for PFAS control is optimisation of the GAC treatment process, as they know this is effective at PFAS removal.

GAC treatment was installed at the site in the early 1990's as part of the Maximum Admissible Concentration (MAC) programme of work to manage the pesticide risk at Ardleigh WTW. The Innovation Team developed extensive research using Rapid Scale Column Tests with GAC media spiked with atrazine and simazine with the aim to assess breakthrough. This work was key at informing the current regeneration policy whereby Anglian Water regenerates all direct abstraction sites every 6 years, impounding reservoir sites every 8 years and groundwater sites every 8 years. Sites with heightened risk are regenerated more frequently. The current regeneration programme is driven by pesticide risk.

The Anglian Water regeneration policy requires the carbon iodine number to be above 600 mg/g upon regeneration (and return back to site), to allow for optimal adsorption capacity of the media. A number of the filters will have had some media top up due to furnace losses or operational losses, however the majority of the carbon will be the original carbon installed under the MAC schemes.

The Anglian Water policy on Empty Bed Contact Time (EBCT) requires an EBCT of a minimum of 30 minutes for direct river abstraction sites and a minimum of 15 minutes for pumped and impounding reservoir sites, bankside storage and groundwater sites. The existing GAC plant at Ardleigh is designed to this policy requirement.

As detailed above, the regeneration frequency is based predominately on pesticide risk, it is not currently based upon PFAS risk. Research undertaken by Anglian Water in 2006 concluded the carbon was effective at PFOS removal. Refer to section 'Research, Pilots, and Technology Development' for further information about the trials.

Preferred, Best Value, Option 1

GAC media replacement with virgin GAC media in all 5 contactors (each contactor is 100m^3, so a total volume of 500m^3) provides a more robust reduction in risk.

Least (Capex) Cost Option 2

GAC media replacement with virgin GAC media in all 5 contactors (each contactor is 100m^3, so a total volume of 500m^3) provides a more robust reduction in risk.

Alternative Option 3

Blending – not viable as no other source to blend with.

Option Assessment Approach

Economic Assessment

The derivation of the benefits that form part of Anglian Waters cost benefit analysis (CBA) consists of two parts, the private value (i.e. the direct cost to Anglian Water avoided by improving service) and a societal/environmental value (i.e., the customer valuation of the benefit of improving service. This is derived predominantly from Anglian Waters 'willingness to pay' research).

For drinking water quality improvements, they have a series of measures used to assess the benefit of investment. These include;

- physio-chemical (iron, manganese and turbidity), hydrocarbon and solvents, pesticides, lead, nickel, nitrate and 'other' chemical parameters

There are other measures which may be considered appropriate to include in the CBA depending on the individual case (i.e., microbiological, aesthetics, Water Quality Notices (i.e. boil/do not drink/do not use)) along with a set of common (water/wastewater) measures such as prosecution.

Cost Estimation

Replacement of virgin GAC costs:

Option (alternative)	Capital Cost (£k)	Opex cost (£k)
I040029 Ardleigh WTW	1,389.98	NA

Benefit Estimation

Anglian Water assessed the pre- and post-investment position in terms of number and likelihood of failures per year, the number of properties or population affected, and the severity of the failure (where appropriate) over a 40-year period. The private and societal values are then applied to provide the overall calculation of benefit. This is then assessed against whole life cost to produce a 'value' score, which is the difference between the discounted sum of benefits over the discounted sum of costs over the 40-year period (this is based on OFWAT guidance at PR09 and is now used as an industry standard). Where this is positive, they can conclude the investment is cost beneficial. This investment is cost beneficial.

Cost Efficiency

The evidence from research is that PFAS is ubiquitous in the environment. In the UK only PFOS and PFOA are regulated. This does pose significant challenge on catchment management activities to reduce PFAS risk within the catchments.

Anglian Water are at the very early stages of understanding PFAS risk having recently completed our revised catchment risk assessment. Coupled with this they have a limited sampling data set on our very high-risk sources, however the results we to date will start to inform catchment investigations and subsequently understanding and development an approach to catchment management options where feasible. Sampling results confirm that PFAS compounds are already in the catchment so therefore optimisation of the GAC treatment process is the only option currently for the sites listed in this proposal.

Assumptions Made

The Cranfield research into the evaluation of PFAS removal of F400 GAC media and subsequent breakthrough has also informed this proposed option. The study was based upon ground water challenged carbon not a surface water carbon which will be more heavily laden with organics. This will also be an additional gap in our knowledge currently, although at Grafham WTW a surface water site for example that there is currently little removal of PFAS compounds from the raw water.

Uncertainties and Sensitivity Analysis

Due to the timing of sampling for the 47 compounds, current data set is limited. Therefore, Anglian Water have based their preferred option on the catchment risk assessments, limited sample data to date and uncertainty of effects on seasonality, hydrological conditions in terms of precipitation and surface or groundwater flows, pumping regime and any other relevant factors which could be applicable.

Carbon Assessment

To facilitate an effective and efficient process to look at the implications of the PR24 Business Cases on carbon (operational and embedded), biodiversity, including Biodiversity Net Gain and Natural Capital all Business cases were screened with relevant Business case leads to ascertain where there was potential for material impact on Carbon, Biodiversity or Natural Capital. Once the potential for an impact was identified the significance associated with that impact was explored with relevant specialists and business case leads.

Surgery sessions were held with business case leads to set out considerations for each of the three assessment areas. Criteria to assess significance of carbon impact included:

- A material increase or decrease in operational CO_2 emissions and/or
- An impact on capital carbon, e.g. identification of requirement for a physical build or change in capital maintenance resource use.

The operational carbon (resulting from energy and chemical use) were assessed using Affinity Water's bespoke asset carbon estimation tool which includes over 400 different carbon models covering the types of below ground and above ground assets we typically construct and operate. The outputs of the carbon assessment (as tCO2e) were fed into the cost benefit analysis for each business case option and monetized to inform assessment of the best value options.

AW Carbon Quantification Tool v1 for PR24 Business Cases - Operational Carbon Tab Figures:

	Units	$kgCO_2e$/unit	m^3 AMP8 (5 years)	kg GAC	Carbon Emissions (kgCO2e)
Option 1. Do nothing (Regen GAC frequency at Ardleigh WTW is 8 years)	kg	2.000	326	154,850*	**309,700**
Option 2. Virgin media	kg	10.000	500	237,500*	**2,375,000**

*Backwashed and drained Bed Density (kg/m3) = 475

Biodiversity Net Gain (BNG) Assessment

The options being proposed by Anglian Water in this business case do not include construction work and have been assessed as no potential for material impact on Biodiversity at the site, so consideration of BNG is not required.

Third Party Assurance and Audit Trail

The information in this business case has been supplied to us by Anglian Water and would therefore be subject to their assurance processes.

Option Assessment

Commentary on the Economic Assessment

The derivation of the benefits that form part of Anglian Waters cost benefit analysis (CBA) consists of two parts, the private value (i.e., the direct cost to Anglian Water avoided by improving service) and a societal/environmental value (i.e., the customer valuation of the benefit of improving service. This is derived predominantly from willingness to pay research).

Preferred, Best Value, Option

The preferred option is replacement of GAC media with virgin carbon. Thereby optimising the efficacy of the carbon which will have a significantly higher iodine number compared to the existing GAC media after regeneration and thus overall adsorption capacity.

GAC is recognised as a treatment process which is effective at PFAS removal. All of Anglian Waters surface water sites and a number of groundwater sites have GAC treatment, principally installed for pesticide removal or in some instances for a specific contamination event such as solvents.

Anglian Waters regeneration policy is based upon pesticide risk and breakthrough of individual pesticides and is dependent on the raw water source. Their EBCT is also dependent on the raw water source. Their PFAS sampling strategy has directly informed their thinking on whether a further approach is required as an interim measure to reset the clock on optimal removal of PFAS compounds from GAC media. The best option of achieving this is with virgin GAC which has a significantly higher iodine number than the current regenerated media we receive, this will be in excess of 1000 mg/g compared to 600 mg/g to 650 mg/g of newly regenerated carbon.

Cranfield research into the evaluation of PFAS removal of F400 GAC media and subsequent breakthrough has also informed this proposed option. The RSSCT was based upon ground water challenged carbon not a surface water carbon which will be more heavily laden with organics. This will also be an additional gap in knowledge currently, although at Grafham WTW a surface water site for example that there is currently little removal of PFAS compounds from the raw water.

Virgin replacement will optimise this treatment stage reducing the risk of PFAS breakthrough and therefore the potential for elevated PFAS levels in the final water.

Least Cost Option 2

As above.

Alternative Option 3

Blending – not viable as no other source to blend with.

Meeting Affinity Water's Outcomes

The requirement for this investment is to meet the commitments set out in our Strategic Direction Statement to "Deliver what our customers need, ensuring affordability for all," which encompasses "Exceed[ing] customers' expectations for drinking water," and to "Be prepared for change and resilient to shocks and stresses".

The primary performance commitment relevant to this business case is CRI (compliance risk index). By investing in treatment solutions, we are ensuring that we are safeguarding water quality for our consumers, now and in the future, in the most cost-efficient way.

The secondary performance commitment linked to this business case is unplanned outage, as a water treatment works will be turned off and taken out of operation if the concentration of PFAS chemicals is too high for us to be able to adequately ensure we can meet water quality regulations at consumer properties.

The requirement for this investment is to meet the commitments set out in our Strategic Direction Statement to "Deliver what our customers need, ensuring affordability for all," which encompasses "Exceed[ing] customers' expectations for drinking water," and to "Be prepared for change and resilient to shocks and stresses".

Justification of the Preferred Option

Alternative options that have been considered in addition to virgin GAC is an enhanced GAC regeneration frequency. Anglian Water reviewed the potential for enhanced GAC regeneration frequency at 'very high-risk' catchment sites. However, acknowledging the significant organic loading that the surface waters have, this adds to the loading of macro pores etc of the carbon and coupled with the carbon age Anglian Water believe the proposal to replace with virgin carbon provides a more robust reduction in risk.

Anglian Water are in the infancy stages of developing their understanding of which catchment engagement options are available to reduce further input of PFAS compounds into raw waters where feasible. This could potentially include working with their trade effluent team, sampling under the Chemical Investigation Programme and working with local high-risk users within the catchments (for example airports, and RAF bases). Some of these work streams are under development currently, further areas of work will be developed for implementation in AMP8 as they gain a greater understanding of the PFAS risk.

The outputs from the Cranfield research support that newer GAC with higher iodine numbers, and with a higher EBCT as the best-case scenario to minimise the risk of PFAS breakthrough. Virgin GAC provides high iodine numbers in excess of 1000 mg/g. This proposal means that out carbon treatment stage will be at an optimal level for PFAS reduction. Anglian Water sites are designed for a 15 minute and 30-minute EBCT, virgin replacement provides the best optimisation option versus regeneration until they are more certain in their own risk. Regeneration will continue to support this option.

Delivery Considerations

Related Projects

Replacement of virgin GAC is proposed at all of Anglian Waters all surface water sites, and 5 listed ground water sites to be completed by the end of 31 March 2030.

Lessons Learnt

Beck Row innovation trials in 2006 on the efficacy of the GAC media at removing PFOS. That research concluded the carbon was effective at PFOS removal. Each filter has historically been regenerated every 2 years at Beck Row, due to the PFOS risk.

Research with Cranfield University to undertake a project on the efficacy of the regenerated carbon testing with Beck Row raw water and carbon, comparing newly regenerated and the oldest GAC media from the site. The summary of the findings was as follows:

- Removal is better at longer contact times and with newly regenerated carbon;
- Removal is dependent on structure of the PFAS compound (number of carbons and chain length) as well as functionality; and
- Bedding in time still being established.
- Even with newly regenerated carbon at longer EBCTs, breakthrough of some PFAS occurs within 5,085 bed volumes namely: PFHxA (perfluorohexanoic acid) and PFPeA (perfluoropentanoic acid).

All of this data and information was used to develop the PFAS management strategy for Ardleigh WTW.

Delivery Risk Management

Phasing of each works will need to be planned and agreed with Anglian Water's GAC framework suppliers, preliminary discussions are currently ongoing.

Further detail regarding how we have ensured the deliverability of our full investment portfolio is provided within AFW 32 Deliverability of our Plans.

Monitoring and Reporting of Benefits

Anglian Waters monitoring strategy for PFAS includes the monitoring of all raw water sources and associated final waters on a risk-based approach. All 'very high-risk' sites will be sampled monthly for the 47 compounds. Additionally, they will monitor each filter twice a year for PFAS to measure the efficacy of each filter as part of their risk-based approach. Any additional monitoring in addition to the above will be detailed within Anglian Waters PFAS strategy for AMP8.

Supporting Information

1. DWI Chief Inspector's report, 2022

Table 7.

The number of test results from raw water PFAS monitoring

Company	Total raw water tests analysed	Results below LOD	Tier 1 - <0.01 µg/l	Tier 2 - <0.1 µg/l	Tier 3 - ≥0.1 µg/l
AFW	10,652	9,999	14	566	73
ANH	121,732	116,951	4,474	285	22
BRL	2,115	1,987	113	15	0
CAM	2,822	2,807	15	0	0
ISC	799	771	21	7	0
NES	4,136	3,704	418	14	0
PRT	4,608	4,477	119	12	0
SES	366	299	66	1	0
SEW	10,976	10,610	280	86	0
SRN	12,462	11,958	406	98	0
SST	7,627	9,684	295	59	0
SVT	2,538	2,518	20	0	0
SWB	1,739	1,730	9	0	0
TMS	1,037	728	300	9	0
UUT	5,290	4,996	271	23	0
VWP	57	57	0	0	0
WSX	1,116	1,067	43	6	0
YKS	12,403	12,195	206	2	0

At Tier 2, companies are required to monitor raw and final water, and review their control measures in consultation with health authorities and the Inspectorate. The Tier 3 results at Affinity are from 5 sites which are subsequently blended, and the Tier 3 results from Anglian are from two groundwater boreholes, which are also subsequently blended.

Table 8.

Number of treated water samples in Tiers 1, 2 and 3 by company

Company	Total treated water tests analysed	Results below LOD	Tier 1 - <0.01 µg/l	Tier 2 - <0.1 µg/l	Tier 3 - ≥0.1 µg/l	Tier 3 in supply
AFW	4,118	3,966	9	143	0	-
ANH	120	14	106	0	0	-
BRL	752	634	83	35	0	-
CAM	1,977	1,971	6	0	0	-
ISC	470	454	14	2	0	-
NES	4,535	3,712	774	49	0	-
SES	636	499	136	1	0	-
SRN	83,868	82,067	1,688	111	2	0
SST	6,091	3,567	190	37	0	-
SVT	376	368	8	0	0	-
SWB	2,492	2,486	6	0	0	-
UUT	2,790	2,571	199	20	0	-

2. Technology options research

Evidence from the supplies and U.S. Environmental Protection Agency (EPA) recognise GAC and Ion exchange as proven treatment technology for PFAS removal. Their research and guidance documents highlight the effectiveness of both treatment processes in reducing PFAS concentrations in drinking water. We have also learnt from the experiences of other water companies who have implemented PFAS removal treatment and will draw on our own experiences with implementing GAC treatment for PFAS as part of the accelerated funding project at Holywell WTW.

EPA treatability information[15] - Evidence from the EPA treatability database suggests good PFOS removal rates (>90%) were seen with A600E resin in a study reported in Water Research in 2016 [16]. This work focused on the application of three strong anion exchange resins (Purolite® A520E, A600E and A532E) for the removal of traces of PFOA, PFOS, PFBA and PFBS concentrations from drinking water.

Evidence from the study using transmission electron analysis on saturated resins showed that large molecular macro-aggregates of PFAS can form in the

[15] EPA Treatability Database PFAS

[16] 'Use of Strong Anion Exchange Resins for the Removal of Perfluoroalkylated Substances from Contaminated Drinking Water in Batch and Continuous Pilot Plants' Zaggia, A., Conte, L., Falletti, L., Fant, M., and Chiorboli, A

intraparticle pores of resin indicating that ion exchange is not the only mechanism involved in PFAS removal. Other data obtained from the experiments showed higher sorption capacity for longer chained sulphonic group compounds, which are the prevalent PFAS compounds seen at Wheathampstead.

The study also indicated that A600E removal rates decreased following regeneration and it is likely that irreversible saturation phenomena take place in A600E which cannot be resolved by the 0.5% NH4Cl and 0.5% NH4OH regenerating solution used in this study. However, the study notes that in this event an extraordinary off-site regeneration using 80% ethanol þ 1% NH4Cl, which has proven effective in restoring 100% of the PFAS removal capacity in batch experiments, could be adopted. Discussions with the manufacture on this have been inconclusive on the longer-term impacts of using the chromium (IV) resin for PFAS removal.

Our chromium (VI) resin ion exchange trial at Wheathampstead WTW ran from May to August 2021.

- Resin was being regenerated approximately once per fortnight, from w/c 29 March through to the start of August 2021.
- The last run started 4 August 2021 and breakthrough for chromium (VI) was seen around 9 August 2021. However, we left the plant running until 25 August 2021 and no PFOS breakthrough was seen in the subsequent two weeks.
- Table 7 below shows the PFOS concentrations in the inlet (borehole 2) and outlet of the chromium (VI) ion exchange pilot plant. PFOS concentrations post treatment was less than the analytical limit of confidence.

Table 7. PFOS concentrations in the inlet (borehole 2) and outlet of the chromium (VI) ion exchange pilot plant.

Sample Date	Wheathampstead Raw 2 PFOS concentration µg/l	Wheathampstead Agua DB Pilot Plant Outlet PFOS concentration µg/l
26/05/2021	0.08	<0.014
28/05/2021	0.083	<0.014
31/05/2021	0.066	<0.014
01/06/2021	0.061	<0.014
04/06/2021	0.116	<0.014
07/06/2021	0.095	<0.014
09/06/2021	0.142	<0.014
11/06/2021	0.125	<0.014
14/06/2021	0.081	<0.014
16/06/2021	0.088	<0.014
18/06/2021	0.087	<0.014
21/06/2021	0.091	<0.014
23/06/2021	0.086	<0.014
25/06/2021	0.077	<0.014
28/06/2021	0.174	<0.014
30/06/2021	0.09	<0.014
02/07/2021	0.088	<0.014
05/07/2021	0.088	<0.014
07/07/2021	0.091	<0.014
11/07/2021	0.09	<0.014
13/07/2021	0.084	<0.014
14/07/2021	0.083	<0.014
16/07/2021	0.087	<0.014
19/07/2021	0.085	<0.014
21/07/2021	0.081	<0.014
28/07/2021	0.081	<0.014
30/07/2021	0.087	<0.014
02/08/2021	0.083	<0.014
06/08/2021	0.092	<0.014
13/08/2021	0.048	<0.014
16/08/2021	0.068	<0.014
18/08/2021	0.07	<0.014

Baldock Road/Bowring assessment of location of GAC within the treatment train:

TCE's like PFOS are organic contaminants, evidence from a study[17] comparing PFAS removal across multiple groundwaters for eight GACs and alternative adsorbent also investigated the impact of TCEs on PFOA removal performance. They concluded that solvents like TCEs will negatively impact PFOA adsorption and corresponding time to GAC changeout at sites with VOCs co-contamination with PFAS.

[17] Comparing PFAS removal across multiple groundwaters for eight GACs and alternative adsorbent. Manmeet W. Pannu, Joseph Chang, Ricardo Medina, Scott A. Grieco, Michael Hwang, Megan H. Plumlee.

Affinity Water

Raw Water Deterioration Programme

Nitrates at Kingsdown and Broome WTWs and Stortford Resilience

July 2023

Contents

Summary

The concentration of nitrate is increasing in the raw water abstracted at Kingsdown, Broome and Stansted WTWs, to the extent each of the sites has had to be turned off during periods of high nitrate levels, and modelling indicates it will not start to decrease for years to come. Additionally, the Stortford supply area supplied by Stansted WTW has a high resilience risk, due to limited storage and the configuration of the network. There is provision in the draft WINEP for some catchment management (CM) schemes in this area for AMP8; the benefit from the CM schemes will be realised in the long-term and will not reduce the amount of nitrate already present in the soil layers from historic agricultural use.

The water is required to meet the supply-demand balance in the areas and to maintain resilience of the network. Therefore, we propose new ion-exchange treatment processes at Broome and Kingsdown WTW, for a total investment of £9m. For Stortford resilience we propose installing 1.95 km trunk main [from Forest Hall Booster Pumping Station] and upgrading the boosters as a contingency, for a total investment of £1.94m.

It is critical that this investment at Kingsdown, Broome and Stansted WTWs are made at this time in order to safeguard the supply-demand balance in the Dour and Stortford regions, protect and improve service levels to consumers, and reduce risk of unplanned outage, low pressure and interruptions to supply.

The requirement for this investment is to meet the commitments set out in our Strategic Direction Statement to "Deliver what our customers need, ensuring affordability for all," which encompasses "Exceed[ing] customers' expectations for drinking water," and to "Be prepared for change and resilient to shocks and stresses".

Project Details

AMP8 Spend	2025-26	2026-27	2027-28	2028-29	2029-30	Total
Capex (£m)	3.49	3.26	1.55	3.26	0.00	**11.56**
Opex (£m)	0.01	0.09	0.09	0.20	0.20	**0.58**
Totex (£m)	3.50	3.35	1.64	3.46	0.20	**12.14**
Drivers						
100%	Addressing raw water quality deterioration (grey solutions)					
Benefits						
Loss of Production Capacity (Ml/d) Capex and Opex Savings (£m)						
Economic Analysis						
NPV Costs (£m) (2025-55)		**13.1**	NPV Benefits (£m) (2025-55)			**19.6**
NPV (£m) (2025-55)		**6.5**	Benefit / Cost Ratio			**1.5**
Six Capitals						

Natural	Social	Financial	Manufact.	Human	Intellectual
	★ ★ ★	★	★ ★		

Project Description

Nitrate is a soluble form of nitrogen that is naturally present in the environment, from both natural and anthropogenic sources. The Drinking Water Directive (DWD) sets the safe nitrate concentration as NO3 in drinking water at a maximum of 50 mg/l, but, due to limitations of monitoring equipment, our current management strategy is to cease abstraction from a source when a monitor reaches a trigger of 47 mg/l NO3.

We minimise and manage the nitrate present in our raw water sources through catchment management and land-user engagement approaches. Where this is not sufficient to fully mitigate the water quality risk, and the concentration is forecast to exceed our 47 mg/l limit or where an unacceptable loss of resilience will result from ceasing operation of the WTW, we propose to implement treatment or blending solutions.

We propose to install a new ion exchange treatment plant at **Kingsdown WTW** to ensure fully compliant water from the treatment works and to safeguard the supply-demand balance in the Dour region and the level of service to our consumers.

We propose to install a new ion exchange treatment plant at **Broome WTW** to ensure fully compliant water from the treatment works and to safeguard the supply-demand balance in the Dour region and the level of service to our consumers.

We propose to install a 1.95 km trunk main from Forest Hall Booster Pumping Station and install upgrades to enable contingency booster operation to enable blending at Stanstead WTW, to ensure fully compliant water from the treatment works and to safeguard the supply-demand balance in the **Stortford** region and the level of service to our consumers.

Project Development

Baseline Assessment

1. Nitrates

Nitrate is a soluble form of nitrogen that is naturally present in the environment. It is produced during the decay of vegetable matter in soil and may be added as a fertiliser to arable land. Rainfall washes nitrate from the subsoil into ground and surface water and this can give rise to elevated concentrations in drinking water. The latter process can take many years, or even decades, depending on the geology of the area.

In early AMP7, work was carried out by Stantec to review our catchments at risk from nitrate contamination. The scope of the work included:

- Review of historic groundwater levels and nitrate concentration trends,
- Review of the catchment characterisation, including soil type, geology, and land use activities,
- Refitting actual data to the Amec Foster Wheeler (2016) forecasts to review future predictions, acknowledging that actual peak concentrations often exceeding the predicted maxima,
- Carrying out spatial assessment of the highest nitrate loading regions of the source catchment and the likely travel time to the abstraction point, and
- Forecasting the likely nitrate concentrations on the sites in the future.

The analysis was completed to identify catchments where we believed some additional investigation and intervention could lead to reduction in the concentrations of nitrate in ground waters. Stantec modelled the potential improvement that could potentially be achieved through implementation of these measures. However, while some opportunities were identified for these three sites, any activities that we do progress are likely to take decades rather than years to result in reductions which are significant enough to remove the need for treatment stages. This is borne out in the projected concentration of nitrate.

It is therefore recommended that some further nitrate blending/treatment will be required at Kingsdown, Broome and Stansted WTW to keep the sources in supply. Changes in rainfall patterns have affected some sites historically and ground water flooding mobilises high concentrations of nitrates resulting in short to medium term site outages. [See graph Figure 1 and Figure 2, which correlates high ground water levels and nitrate concentration.]

Regulatory Position for Nitrate in Drinking Water

The Drinking Water Directive (DWD) sets the safe nitrate concentration as NO_3 in drinking water at a maximum of 50 mg/l. The Company has a nitrate strategy which details the current monitoring policy and design standard for nitrate treatment at Affinity Water sites. The nitrate strategy for treatment design standards states that all mitigation options have an absolute limit of 47 mg/l (due to +/- 3 mg/l measurement error) as NO_3 in final water and a statistical target of < 43 mg/l (95 percentile) as NO_3. As such, our current management strategy is that when a site reaches the trigger of 47 mg/l NO_3, (for sites that have no treatment), abstraction is ceased to reduce the risk of exceedances.

Our Drinking Water Safety Plans (DWSP) identification procedure is based upon reviewing water quality monitoring data and identification of operational and consumer risks across the supply system from abstraction to tap. A trigger of any result >50% of the Prescribed Concentration or Value (PCV) is applied to each parameter to identify risks. Nitrate is an exception to this rule, the nitrate risk assessment is based upon the Company's nitrate policy which applies different trigger levels to initiate a response, the initial trigger starts at results >40 mg/l. Water Supply Systems with >10 residual risk of health risk i.e. possible within next 5 years.

Kingsdown, Broome and Stansted WTW raw water sources show increased concentrations of nitrate and residual risk.

2. Kingsdown Water Treatment Works

Kingsdown WTW is located between Dover and Deal in Kent and supplies water to WSZ 078 Dover either directly or via Downsgate Reservoir.

We take weekly operational samples of the raw water at Kingsdown WTW for nitrate analysis. Since 2002, we have taken just over 500 samples. The graph of the nitrate trend in the raw water since 2002 is below (Figure 1. Kingsdown Raw Nitrate Concentrations 2002 to February 2023). There has been a general increase in nitrate concentration over time, from around 34 mg/l in 2002, to approximately 45 mg/l in 2021.

The source has been offline for 6 months in 2020, and 8 months in 2021and 2022 due to nitrate concentrations exceeding 47 mg/l. The source has been offline since January 2023, again due to elevated nitrate.

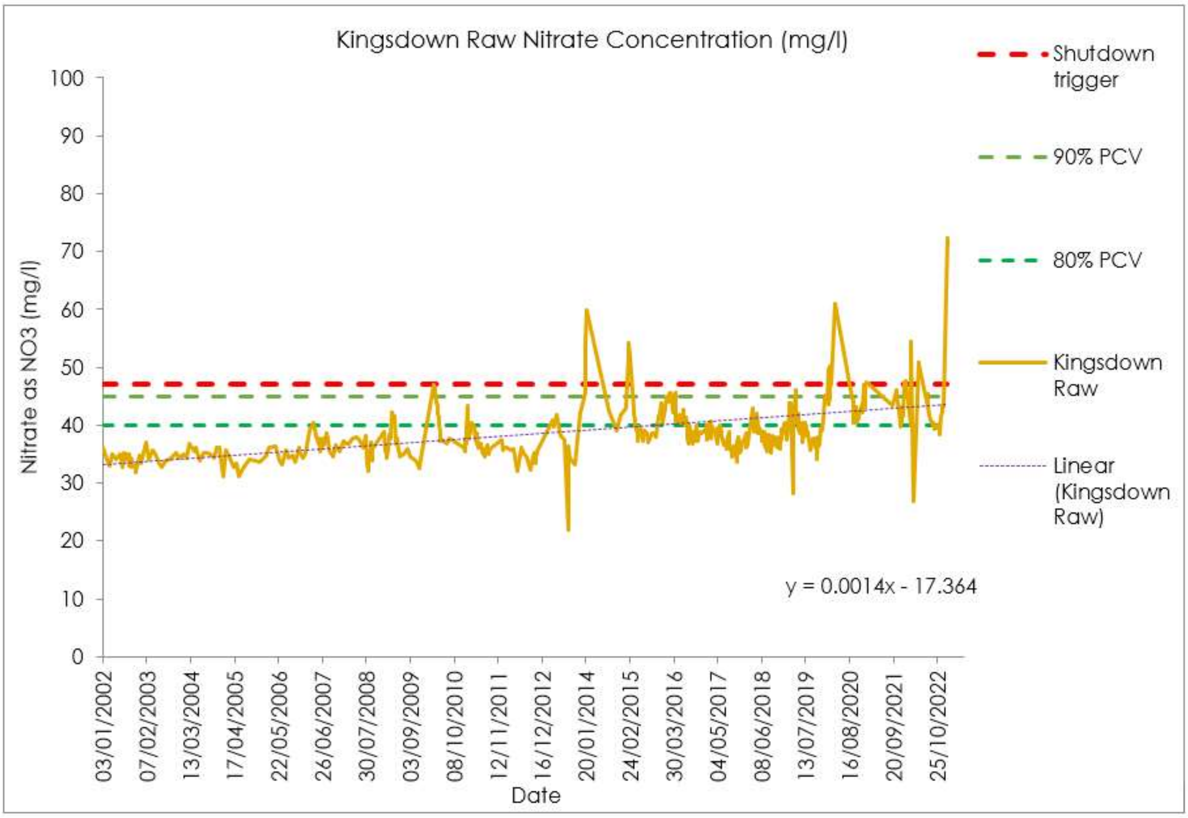

Figure 1. Kingsdown Raw Nitrate Concentrations 2002 to February 2023.

Figure 2. graph below, compares nitrate concentration at Kingsdown to regional groundwater levels at the Wolverton observation/ indicator borehole and shows that the seasonal trend compares well with the pattern seen in the regional indicator borehole. The seasonal response observed in the nitrate concentrations appears to have increased over time.

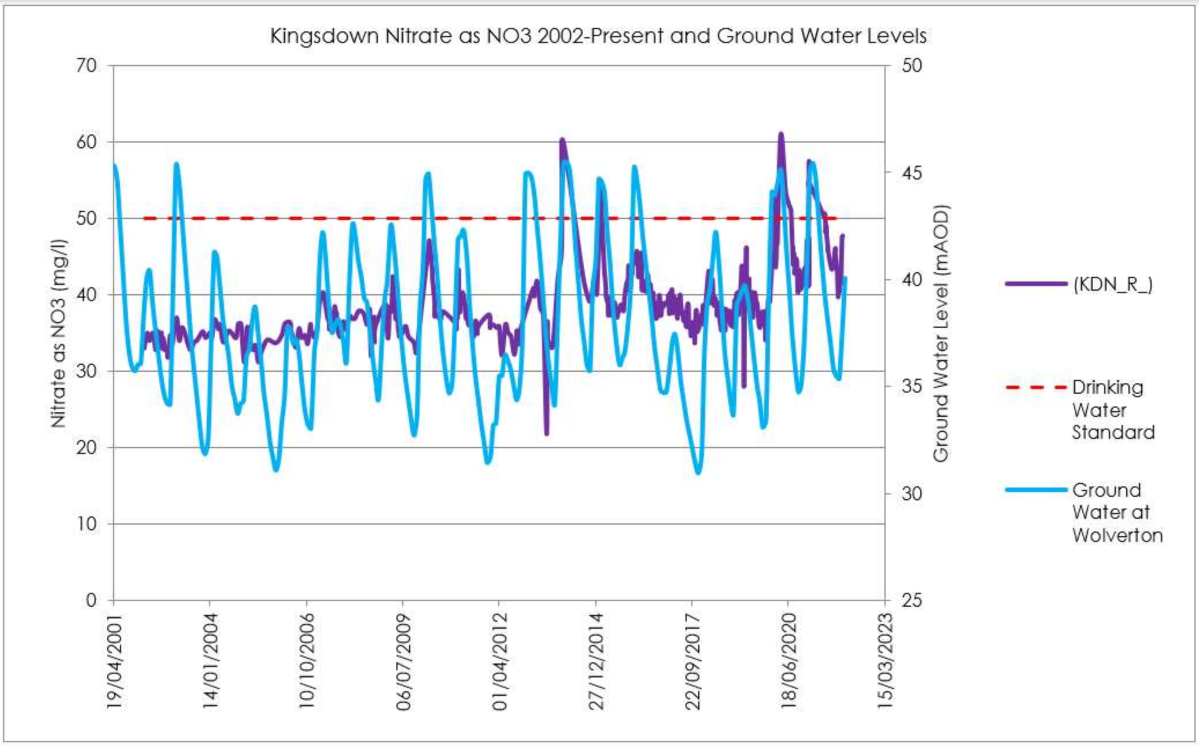

Figure 2. Graph showing Kingsdown Raw nitrate concentration and ground water levels.

Nitrate modelling indicates concentrations will not start to decrease for many years to come[1].

[1] Stantec - Catchment management nitrate modelling: Kingsdown 22/11/2021 Report Reference: 331101445 R1 Appendix D

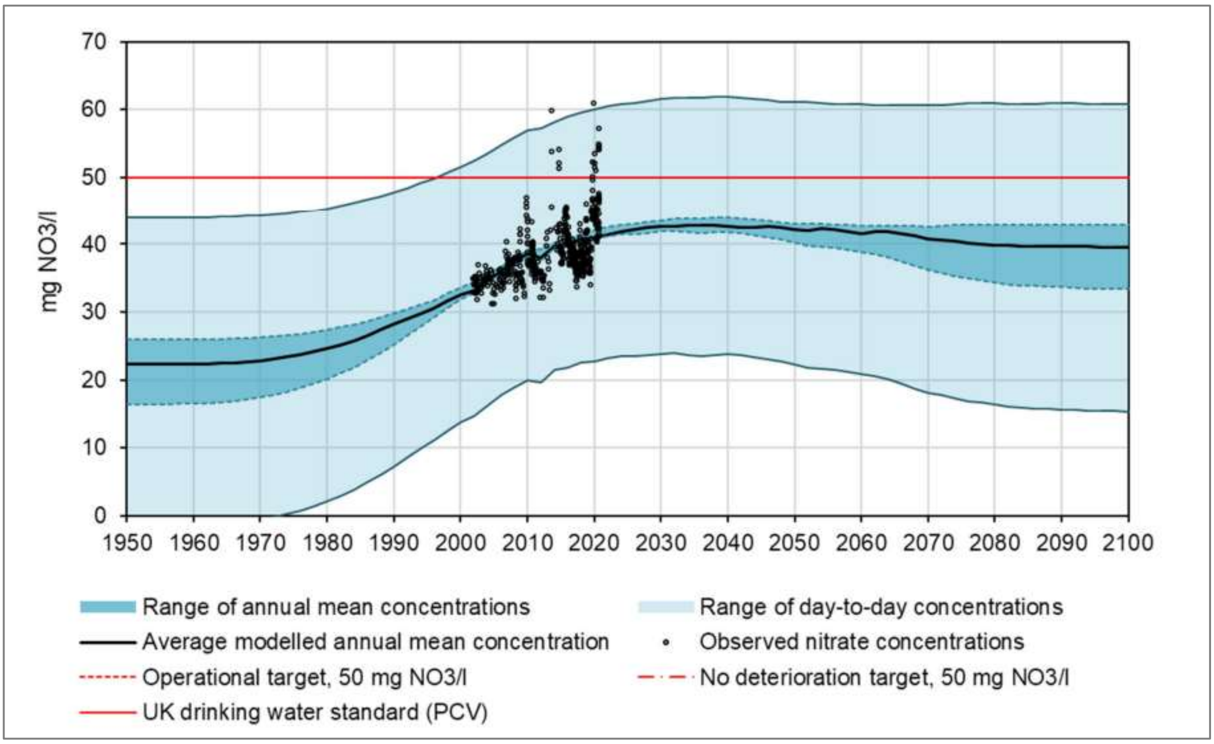

Figure 3. Kingsdown Counterfactual model results.

In the Figure 3. above, the black line does not represent the best fit of the model. Rather, the black line shows the expected annual mean concentration, which could fall anywhere within the dark blue envelope. The dark blue envelope encloses the expected range of annual mean concentrations (5%ile to 95%ile values). The light blue envelope encloses the expected range of sample concentrations (i.e. including peaks).

Summary:

- The fit of the modelled trend to the observed concentrations is generally good, with the hydrogeological parameters used to calibrate the model in keeping with the conceptual understanding of the catchment.
- Concentrations at Kingsdown are predicted to rise until approximately 2030. Peak concentrations are predicted to exceed the PCV over the entire model period (up to 2100).
- Recent observed data (2020 and 2023) shows a large increase in nitrate concentration compared to previous years. Further monitoring of this is required to determine whether this increase continues and therefore represents a change to the long-term patterns observed at Kingsdown.
- Our Catchment Management team (CMT) believes the significant increase in nitrate concentrations may be associated with a livestock farm on the edge of SPZ1 that has doubled the size of its operations over the past 10 years. CMT have been liaising with the EA for some time and the EA have raised concerns related to the new slurry storage infrastructure cutting directly into the chalk and other concerning practices with waste and water management on site. CMT will continue to engage with the farm and EA,

however, enforcement action is unlikely to produce any positive results in the short term.

- There is a strong seasonal pattern in nitrate concentration at the abstraction, related to the variation in groundwater levels i.e. peaks in nitrate concentration follows peaks in groundwater levels. Figure 2. Graph showing Kingsdown Raw nitrate concentration and ground water levels below.
- Observed nitrate peaks typically occur between January and April, with the most recent peak being >70 mg/l. There is potential for double seasonal peaks to occur following winters with the most recharge.

3. Broome Water Treatment Works

Broome WTW is a groundwater site located near Barham, Kent, and supplies water to WSZ 080 Chalksole and Chalksole Reservoir.

We take monthly operational samples of the raw water at Broome WTW for nitrate analysis. Since 2002, we have taken just over 600 samples. The graph of the nitrate trend in the raw water since 2002 is below (Figure 4. Broome Raw Nitrate Concentrations 2002 to 2022). There has been a general increase in nitrate concentration over time, from around 28 mg/l in 2002, to approximately 34 mg/l in 2021.

Higher concentrations recorded between 2013 and 17, followed by a slight fall in 2016 -18, before concentrations starting to rise in recent data up to 2021.

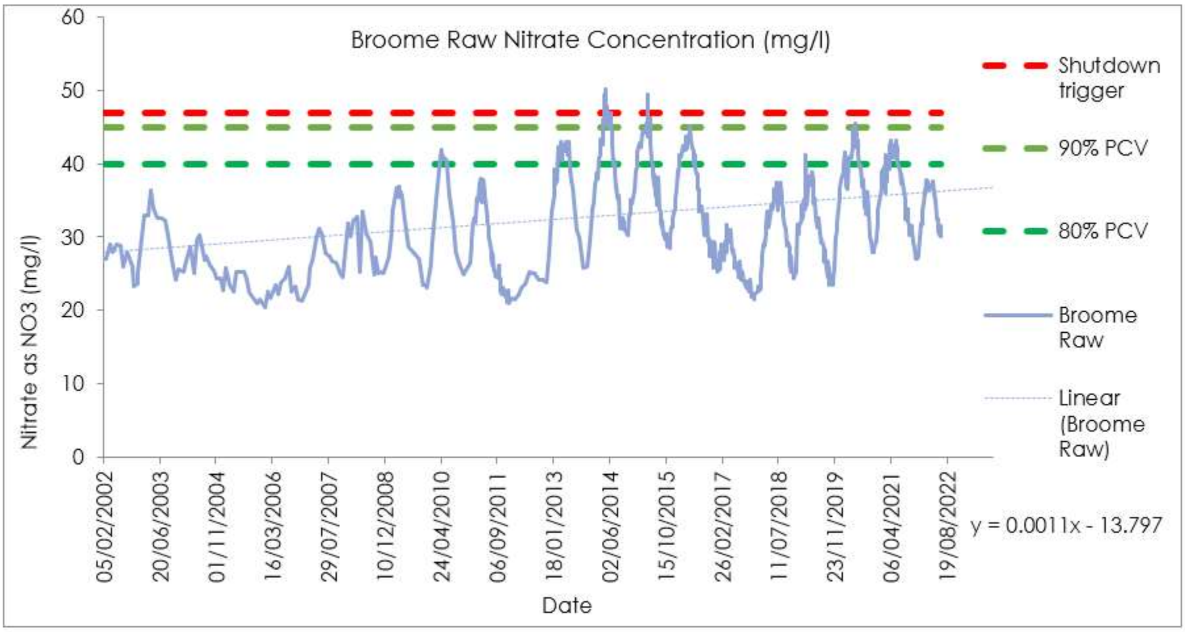

Figure 4. Broome Raw Nitrate Concentrations 2002 to 2022.

Figure 5. below compares nitrate concentration at Broome to regional groundwater levels at the Wolverton observation/ indicator borehole and shows that the seasonal trend compares well with the pattern seen in the regional indicator borehole. The

seasonal response observed in the nitrate concentrations appears to have increased over time.

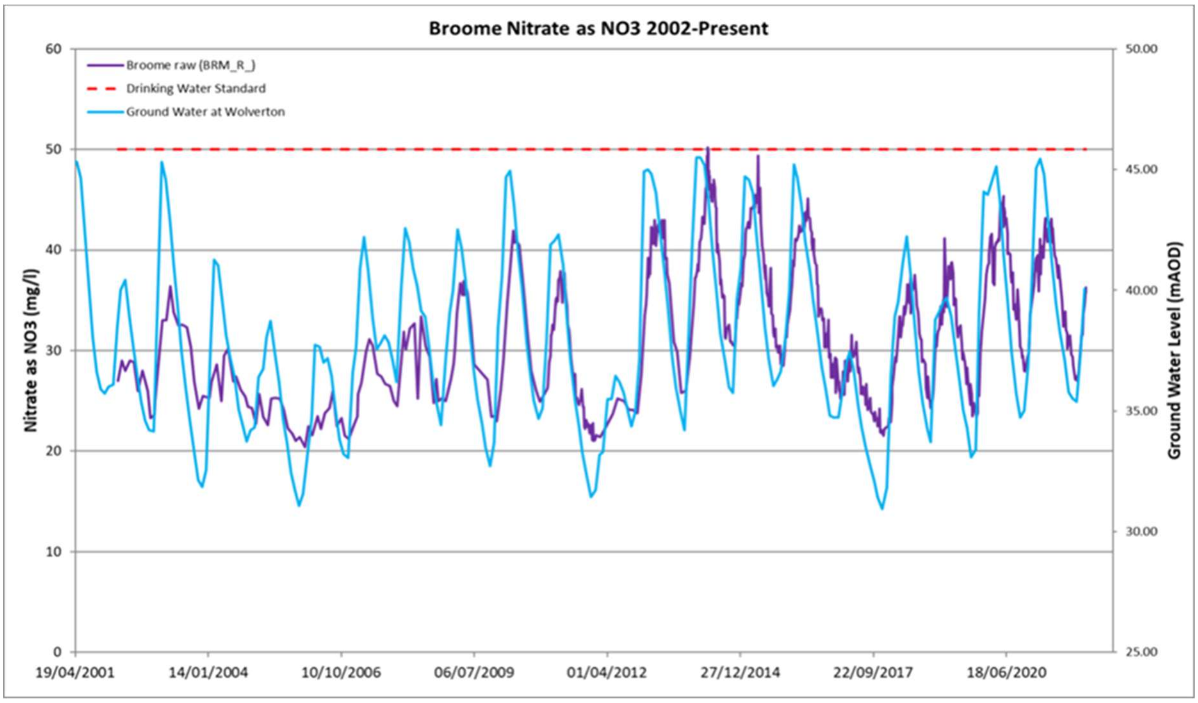

Figure 5. Graph showing Broome Raw nitrate concentration and ground water levels.

Nitrate modelling indicates concentrations will not start to decrease for many years to come[2].

[2] Stantec - Catchment management nitrate modelling: Broome 18/11/2021 Report Reference: 331101445 R1 Appendix A

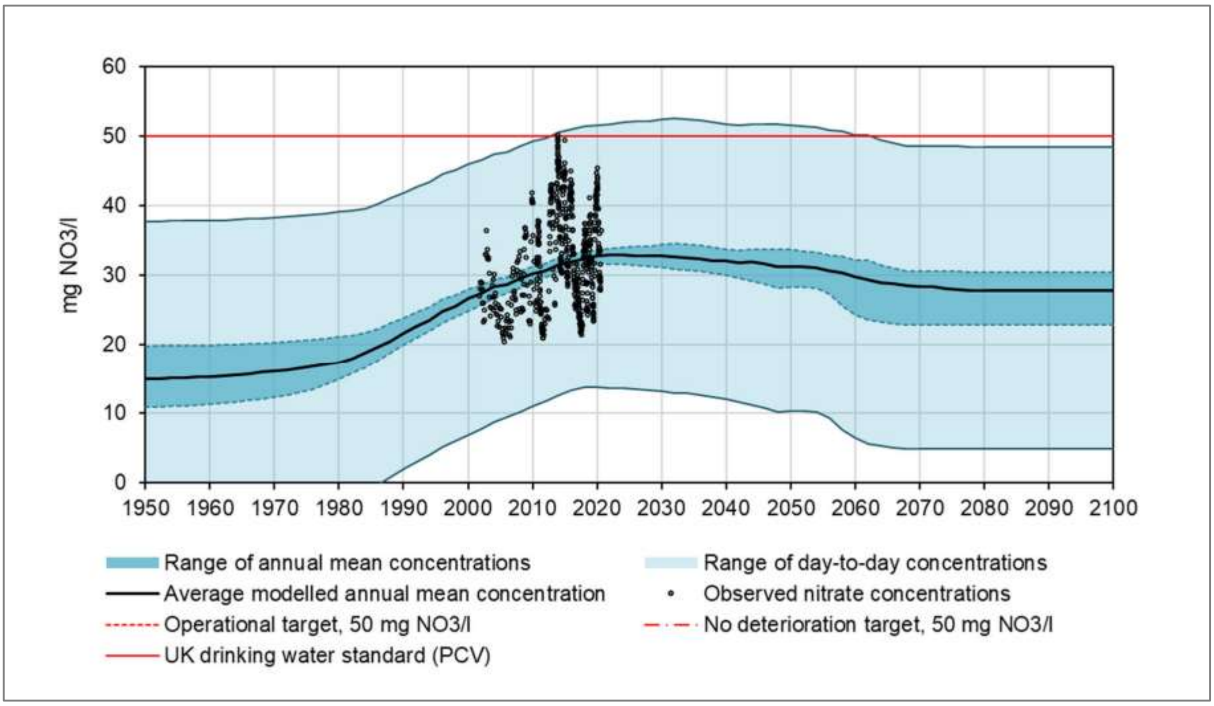

Figure 6. Broome Counterfactual model results.

In Figure 6. above, the black line does not represent the best fit of the model. Rather, the black line shows the expected annual mean concentration, which could fall anywhere within the dark blue envelope. The dark blue envelope encloses the expected range of annual mean concentrations (5%ile to 95%ile values). The light blue envelope encloses the expected range of sample concentrations (i.e. including peaks).

Summary:

- Concentrations show a very strong seasonal pattern developing over time, especially since 2010. Higher concentrations are seen during the winter/ spring period each year, with the highest concentrations of 49 mg/l observed in early 2014 and 2015.
- Observed nitrate peaks typically occur between April and May each year, although these get later during years with greater amounts of recharge.
- There has been one exceedance of the 50 mg/l PCV for nitrate in the record, which occurred in April 2014 with a concentration of 50.2 mg/l.
- Concentrations >47 mg/l seen in 2014 and 2015, >90% PCV seen in 2020. Forecast is for average NO_3 concentration to reach 47mg/ in 2026 and exceed the PCV in 2030. Concentrations at Broome are predicted to rise until approximately 2040.
- Concentrations at Broome are predicted to rise until approximately 2040. Peak concentrations are predicted to slightly exceed the PCV between 2020 and 2060.

4. Stansted Water Treatment Works

Stansted WTW is a ground water site located in a residential area of the village of Stansted Mountfitchet, Essex, and supplies water to Berden Water Tower and WSZ 011 Stansted.

We take weekly operational samples of the raw water at Stansted WTW for nitrate analysis. Since 2002, we have taken just over 800 samples. The graph of the nitrate trend in the raw water since 2002 is below (Figure 7. Stansted Raw Nitrate Concentrations 2002 to 2022). There has been a general increase in nitrate concentration over time, from around 40 mg/l in 2002, to approximately 45 mg/l in 2021. On two occasions, in 2016 and 2020, we have exceeded our 47 mg/l trigger which led to automatic shutdowns of the treatment works.

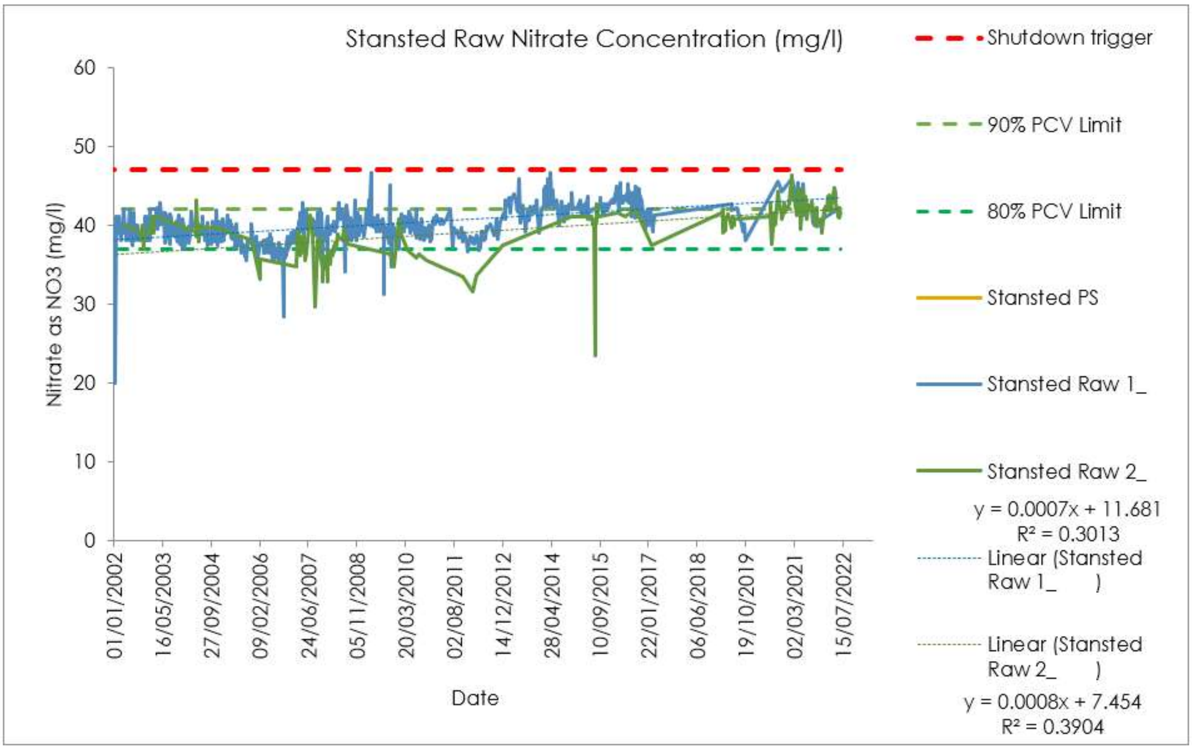

Figure 7. Stansted Raw Nitrate Concentrations 2002 to 2022.

Figure 8. below, compares nitrate concentration at Stansted to regional groundwater levels at the Elsenham Nurseries observation/ indicator borehole and shows that the seasonal trend compares well with the pattern seen in the regional indicator borehole. The seasonal response in nitrate concentrations is quite subdued, but the variation in groundwater levels is similarly subdued for the Chalk, with variation of up to 2 m annually.

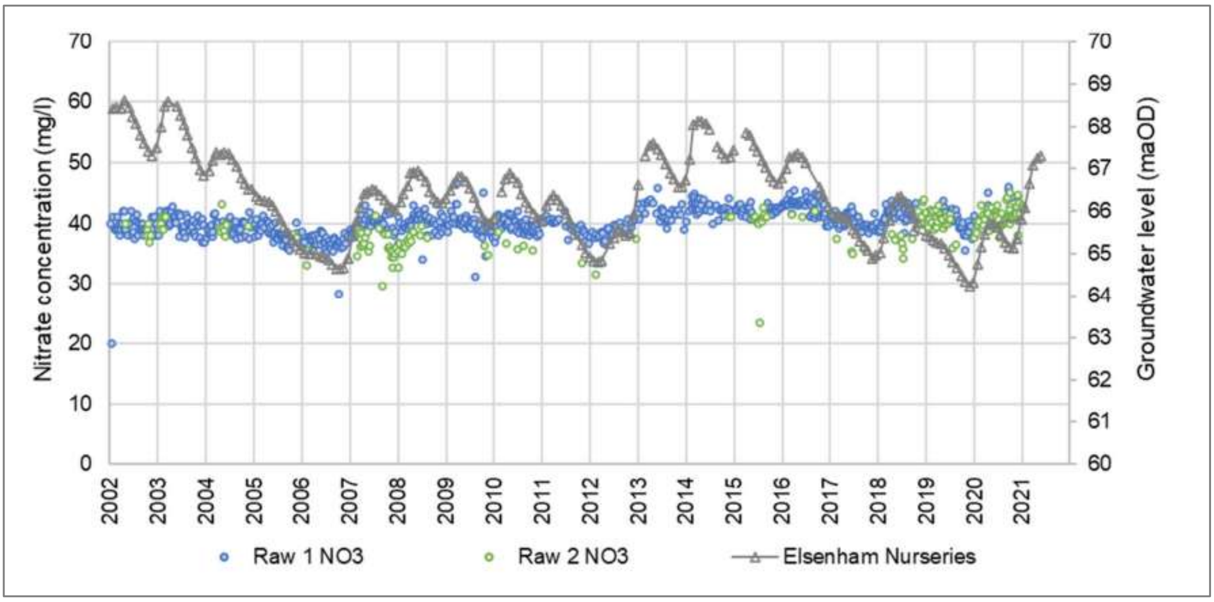

Figure 8. Graph showing Stansted Raw nitrate concentration and ground water levels.

Nitrate modelling indicates concentrations will not start to decrease for many years to come [3] as shown below (Figure 9).

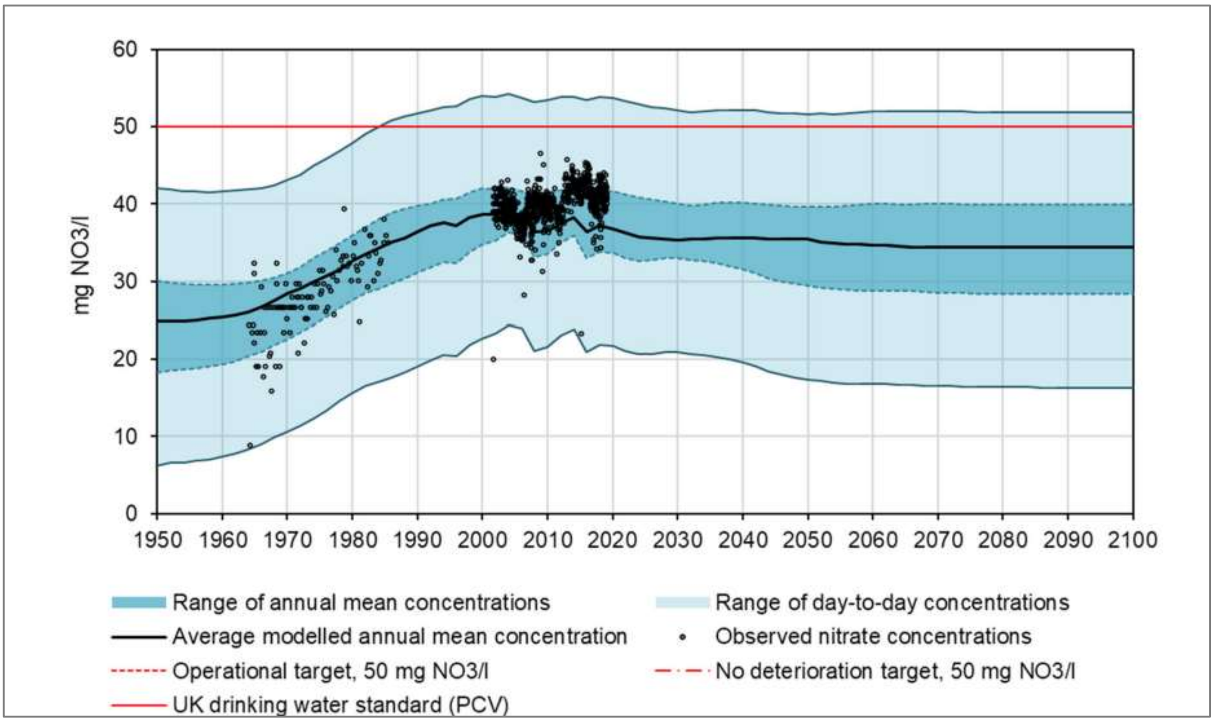

Figure 9. Stansted Counterfactual model results.

Summary:

- Both average and peak concentrations are expected to remain at a similar level until approximately 2035 – 2040 when they will begin to gradually fall.

[3] Stantec - Catchment management nitrate modelling: Stansted 24/11/2021 Report Reference: 331101445 R1 Appendix I

- Annual average concentrations are expected to remain below the PCV throughout the modelling periods. There is 95% confidence the peaks remain below 49.3 mg/l.
- Observed nitrate peaks typically occur between March to April, preceding the groundwater level peaks observed at the Elsenham Nurseries observation borehole by around 1-2 months. In years with higher winter recharge the observed nitrate peaks tend to occur earlier in the year.

Problem Statement and Stated Need / Driver

Nitrate is present in the environment and is toxic in terms of human health. The increasing trends in nitrate at Kingsdown, Broome and Stansted WTWs have led us to re-evaluate our risk assessments and we have identified that these water supply systems require investment to ensure water supplies remain wholesome and we can keep this treatment works in supply. Our assessment and optioneering has identified the required investment in AMP8 to ensure continued water availability from those treatment works and to safeguard water quality.

Risks, Issues and Requirements

Nitrate and Resilience

We monitor and manage nitrate concentrations in treated water supplies such that they comply with the current Water Supply (Water Quality) Regulations 2016 prescribed concentration or value (PCV) of 50 mg/l as NO_3.

The frequency of monitoring on each source is determined by the individual risk level. This ensures that we have visibility of changes in raw water quality, and our teams monitor the trends on the water sources to identify any change in risk level.

At all our sources where nitrate concentrations exceed 45 mg/l on more than one occasion in the previous five years, continuous on-line nitrate monitoring with an analogue signal to a telemetry system is installed. We control failing the regulatory standards with alarms via telemetry and shutdown controls to monitor raw water for increasing trend. Where nitrate monitors are installed, the high alarm will be set at 47 mg/l as NO_3.

Risks

The risk, therefore, is to water supply and water availability. If the sources were to be turned off due to increasing nitrate concentrations, then there would be a decrease in water availability in the area. This impacts our resilience, and ability to meet demand. Outages at other sites in turn could lead to low pressure events and loss of supply to customers. With Broome, we would have customer impact of low pressures in the summer when the site is used to boost supplies 24/7, and a DG2 impact would be incurred in the Chalksole zone.

When Stansted site shuts down, there is less than 12 hours' storage to supply the area and the current contingency is to feed from Forest Hall Booster. The supply area has had a high number of bursts in the past and this contingency will exacerbate the issue and leads to interruptions to supply.

Allocation of Costs

The delivery of this scheme is driven by a statutory requirement to maintain potable water quality in the context of deteriorating raw water quality conditions. The investment will result in a step-change in the service level provided to consumers and is therefore Enhancement expenditure.

DPC

This scheme is not suitable to be considered for a Direct Procurement for Customers approach as the value is significantly below the £200m TOTEX threshold.

Research, Pilots, and Technology Development

Ion exchange nitrate removal plants generate sodium nitrate ($NaNO_3$) waste as a by-product. This waste is a result of the regeneration process where the resin in the ion exchange columns is regenerated with a sodium chloride (NaCl) solution to restore its nitrate removal capacity.

However, we have been approached with an opportunity to work with a firm who have developed an alternative approach to the regeneration process. They have developed a method for using potassium chloride (KCl) as the regenerative solution so that the waste stream composition is changed to potassium nitrate (KNO_3). This is a common fertiliser and could potentially be reused in agricultural applications. We are exploring opportunities to trial this regeneration solution as it presents a good opportunity for a circular economy approach to this waste stream.

Customer Engagement

Detail of Customer Engagement work

We have undertaken extensive engagement with our customers to build a detailed understanding of their priorities and reflected these in this business case. For more detail on our customer engagement see AFW04 What Customers and Stakeholders Want.

We carried out some customer engagement[4,5,6,7] as part of the Strategic Resource Options programme of work, looking at how customers preferred to be communicated with. This gave us the opportunity to gain some insights into their thoughts and preferences about several of the long-term plans related to water resourcing, including source types.

An evidence review was carried out of 50 documents and stakeholder interviews with each of the water companies, with documents gathered directly from the 6 water companies involved in WRSE, and the evidence was then synthesised to identify consistent findings which were triangulated to assess their strength. During the qualitative phase we tested these findings with 96 household customers across the 6 companies, including Gen Z and vulnerable customer. During the quantitative phase we held 15-minute online surveys with 1,762 household and 198 non-household customers for robust segmentation and validation of findings.

This research reinforced our understanding that water is a low salience topic with our customers, in that they have a low level of awareness and understanding of issues relating to it. This in part is driven by general satisfaction with the customer experience of water in terms of taste, smell and hardness.

We followed this up with some deep dive sessions in July 2022 to specifically test on our own long-term plans with a wide cross section of our customer base[8]. 82 customers and 10 business representatives participated in this research. Customers were divided into 'household', 'vulnerable' and 'future' groups to reflect a range of views, whilst local business representatives provided views on behalf of their place of work ('Non-household').

The Non-household individuals were recruited from businesses which are heavy water users. Customer groups covered a range of ages, socio-economic backgrounds, and areas within Affinity Water's region in order to enable a diverse range of views. Given the long-term focus of the research, future customers were also included to gauge an understanding of priorities from individuals who are likely to become Affinity Water customers in the future.

[4] WRSE Customer Preferences Part A Evidence Review Final Report eftec ICS February 2021.pdf
[5] Water Club - Changes of Source - June 2022.pdf
[6] Affinity Water Customer Valuation Research Summary Report May 2023.pdf
[7] Affinity Water Customer Priorities for Long-term Ambitions
[8] 'Customer Priorities for long-term ambitions to support PR24 and long-term delivery strategies,' September 2022

Ten online focus groups were held (household and future customers) and fifteen one-to-one interviews conducted (vulnerable and non-household customers). Focus groups were conducted via online video, using the specialist VisionsLive platform, each session lasting 90 minutes. Voting exercises and activities were used throughout the focus groups, to aid engagement, capture strength of feeling, and focus the discussion on the core research questions.

These were qualitative sessions, and the outcomes gave us some insight into customer views of the relative importance to them of, among other considerations:

- Reducing amount of chemicals used in water treatment,
- Reducing carbon emissions associated with treating water for customers,
- Hardness level of their water supply, and
- Keeping customer bills as low as possible.

Finally, we held some quantitative research sessions between February and March of 2023 with a second set of workshops looking at Customer views on priorities covering customer preferences for changing service levels. Customers were generally observed to be more sensitive to avoiding deteriorated service levels compared to the preference for improvements. In general, there was a limited preference for changes in service levels for hard water and hosepipes bans.

911 household customers completed the survey between February and March 2023 800 respondents completed an online survey and 111 completed an in-person interview, qualifying as "digitally disengaged." 42% of the household respondents (383 people) were classified as being in vulnerable circumstances. Around 13% of respondents who took part in the study (117 people) were registered with the Priority Services Register. Of these 117 respondents, 31% were medically dependent on water, 56% suffered from physical issues, and 9% need information in alternative formats.

There was a good distribution among the respondents of all targeted characteristics. Females were slightly over-represented (57% of respondents) and were within +/- 7 percentage of sample quotas. Socio-economic group (SEG) profile was within +/- 3 percentage points of sample quota. All age cohorts were within +/- 4 percentage points of sample quotas.

150 non-household (NHH) respondents completed the survey online. These comprised a good mix of NHHs achieved when measured by both number of sites and by number of employees. Around a third of organisations had only 1 site (34%), 12% of respondents were a sole trader and 15% of respondents had between 100-150 employees. Also, the sample distribution by economic sector has the expected profile with 1% as Primary, 28% as Secondary and 71% as Tertiary.

Evidence of Customer Preferences

We have developed all of this research and analysis into a document called 'What our Customers & Stakeholders Want[9]' which presents the findings from the various customer engagement activities. The key takeaway point from the research is that customers have a high level of inherent trust in us as a water provider, and generally are happy for us to make decisions about technology selection and water quality risk management without consultation with them – we are the experts, and they trust us to make those decisions.

Another outcome of the research was a strong steer that customers expect us to meet our regulatory duties at all times, with respect to the Water Supply (Water Quality) Regulations. Any strategic decisions we make with respect to cost or carbon emission reduction must not have any detrimental impact on water quality performance.

The outcomes from the deep-dive qualitative sessions with our own customers indicated that they have wide ranging responses to the questions of whether we should be reducing chemical use in water treatment and whether we should be reducing operational carbon emissions, which could be influenced by many factors including the respondents' own socio-economic group, with no overall preference or point-of-view expressed[10]. Two thirds of customers did not support investment to soften hard water, with a third supporting investment. Hard water tends to polarise customer opinions. However, there was a clear steer from customers, from these qualitative sessions, that their main priority over any of the other considerations was to keep bills as low as practicable.

The SRO customer communication preferences work indicated that there are some acceptance barriers in place for customers around some of our water resourcing ideas, particularly with respect to direct or indirect wastewater effluent reuse schemes. They indicated that they would need reassurance if this type of approach were taken that water would be safe to drink.

The qualitative research sessions indicated that customers were generally observed to be more sensitive to avoiding deteriorated service levels compared to the preference for improvements. Household customer values for improved service levels for areas including tap water aesthetics was relatively modest – but nevertheless improvement in these areas was viewed as beneficial. In general, there was a limited preference for changes in service levels for hard water and hosepipes bans. Respondents felt that Affinity Water's services are good value for money and were generally satisfied with the services they receive.

Customer protection

We have received a Regulation 28(4) Notice DWI notice for each of the three Nitrates-affected sites in relation to our raw water enhancement scheme that will

[9] What our Customers and Stakeholders Want V5 final.pdf
[10] Line of sight V3.doc

formalise the requirement to deliver the schemes preferred options with date deadlines.

Broome Reference: AFW-2023-00001

Kingsdown Reference: AFW-2023-00002

Stortford [Stansted] Reference: AFW-2023-00004

We have also designed Price Control Deliverables [PCDs] based on the average deployable output recorded for each site, in line with the DWI notice dates. Stortford PCD differs in that it is based on the flow capacity of the new blending main.

Each notice and PCD will ensure delivery of all the customer benefits highlighted in this business case. The Performance Commitments (PCs) that will benefit directly from implementing the proposed protection cover are 'Unplanned Outage' and 'Water Quality (CRI)'. The schemes will also serve to improve resilience, with the associated benefits to ensuring reliable supplies to our customers.

Note that there are no third-party funding arrangements related to these four projects within the Nitrates programme of works.

Partnering

Collaboration and Partnering

Engagement with Stakeholders and Partners

- DEFRA (Department for Environment Food and Rural Affairs)

Accelerated Infrastructure Programme Opportunity – In October 2022, Defra asked water companies to propose schemes for accelerated additional infrastructure delivery in 2023-24 and 2024-25 that would provide benefits for customers, communities, and the environment. Completion of planning permission, detailed design, and delivery contracts were proposed for both Kingsdown and Broome WTW nitrate schemes and submitted our draft business case to the DWI. In April 2023, Ofwat's draft decision supported the acceleration of both schemes proposed.

- Drinking Water Inspectorate (DWI)

We were invited by the DWI to carry out some early engagement with representatives from the regulator through the Autumn of 2022. We met with them during November 2022 and shared an early view of what is likely to be included in the water quality programme for PR24, their initial feedback was supportive of our proposals.

In January 2023 we submitted a summary statement to the DWI which highlights significant new future risk mitigation measures that we will be seeking support for in the PR24 proposals. The purpose of this statement is to:

  - to understand the justification and evidence for proposals
  - to estimate the number and type of submissions to expect

In addition to the summary paper, in March 2023 we submitted to DWI our draft business cases for drinking water quality investments.

- Environment Agency (EA)

We have liaised closely with the EA to develop our WINEP and catchment management plans for PR24, and have taken a holistic approach at an Operational Catchment scale, incorporating:

  - Sustainability reductions (SR's)
  - Abstraction Impact Assessments
  - Biodiversity enhancement
  - Catchment and Nature-based solutions (C&NBS)
    - Revitalising Chalk Rivers - River restoration, habitat enhancement and monitoring
    - Resilient Chalk Catchments - Catchment management measures for multiple benefits (water resources, water quality, biodiversity, carbon, chalk stream resilience)
  - Flagship Chalk Stream Catchment Restoration projects (CaBA strategy)

The engagement process is outlined in the schematic (Figure 10) below.

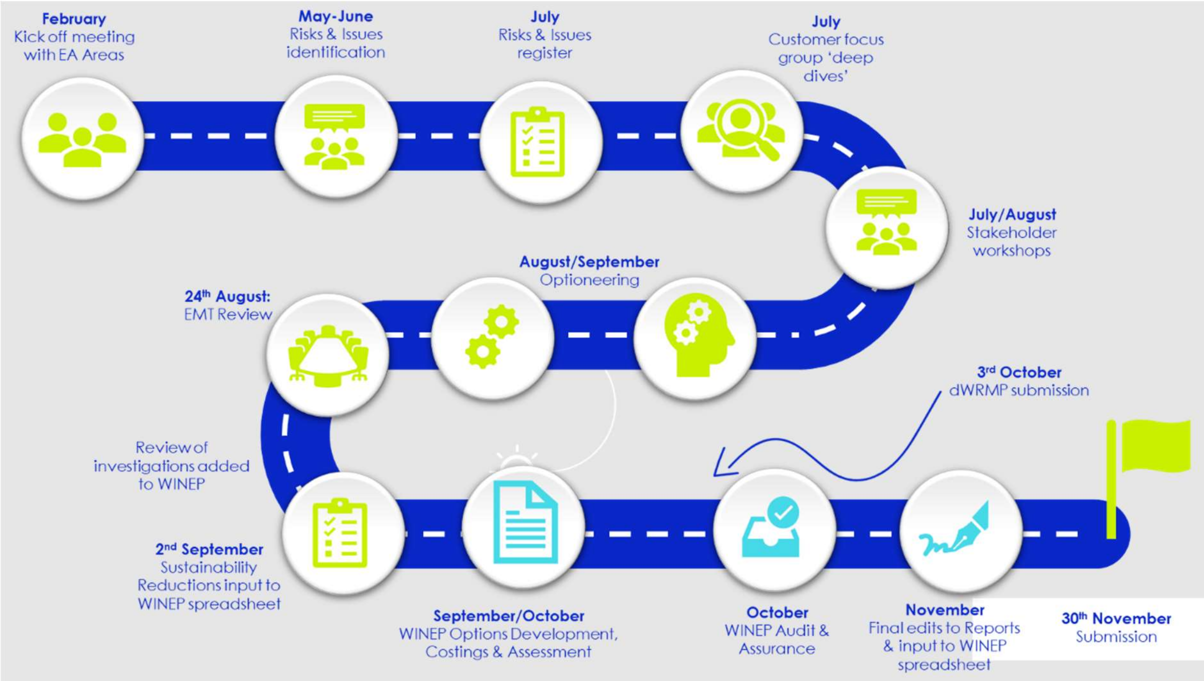

Figure 10. Schematic of our engagement process.

Co-design and Co-delivery

- Inter-company collaboration

We are members of multiple inter-company groups in which we discuss significant emerging risks and potential solutions to or approaches for dealing with them. These include: Water UK (and all the sub-groups therein), UKWIR, WRc (including Disinfection Forum), Cranfield University (including UK Water Network on Potable Water Treatment and Supply), Isle Technologies (Technology Advisory Group, Water Treatment Technical Working Group and Water Distribution Technical Working Group).

- Early engagement with technology suppliers

We often engage early with suppliers of specialist treatment equipment in order to understand the options currently available on the market, as well as those at various stages of development in currently in use in other countries (which may not hold the approvals necessary for use in the UK). We also use information from the suppliers to begin to build up cost estimates for implementation of the novel technologies, for which we do not hold any normalised cost models.

Strategy Development

All of our enhancement cases have been developed as part of our integrated investment portfolio that takes the first steps of our Long Term Delivery Strategy and achieving our ambitions as laid out in AFW03 Strategic Direction Statement.

Long-term Delivery Strategy Alignment

In our Strategic Direction Statement[11] we commit to "Deliver what our customers need, ensuring affordability for all" which encompasses "Exceed[ing] customers' expectations for drinking water." We know that customers hold inherent trust in us to make the appropriate interventions to safeguard their water quality.

There is an additional commitment to "Be prepared for change and resilient to shocks and stresses" within which we commit to "Ensure a resilient supply of water for Affinity Water customers." We are delivering on this commitment in this case by providing treatment or blending where no other management of the risk is possible without detrimental effect on the resilience of our supply network in this area.

Our long-term delivery strategy related to water treatment includes an investment line covering "Addressing raw water deterioration." In this instance, there is a deteriorating (increasing) trend in the concentration of nitrate in the raw water. Without the investment, there is a high likelihood that we will need to cease use of these sources for supply within AMP8.

The investments proposed within this business case are aligned with the Core Adaptive Pathway of our LTDS and will not adversely impact any of the potential Alternate Pathways identified within the LTDS. The investments will still be required under all common reference future scenarios.

Treatment Strategy

Currently, our Treatment Strategy requires provision of treatment only when necessary due to raw water quality and when it is the best value holistic solution to provide treatment rather than any other solution.

We are exploring options around selection of treatment processes that have high power demand in preference to processes that require high chemical input in order to reduce our overall operational carbon emissions. The speed at which we implement this strategy will depend on the glidepath to net zero operational carbon emissions set by the Company, and whether these proactive changes towards power-intensive processes away from chemical-intensive processes are necessary to achieve those target future carbon emission profiles.

[11] AW0031_Strategic-direction-statement.pdf

Adaptive Strategy

Depending on the speed at which we want to reduce our operational carbon emissions on our treatment works, it may be necessary to select a high-power demand process for treatment of nitrate over a high chemical demand process. These operational carbon emissions glide paths will become available to us shortly but are not available right now. For now, we will select best value solution based on cost and risk reduction.

This project is no regrets because we require the water from the sources in order to meet our supply demand balance and, without the addition of treatment processes at these sites, we predict that these sites will otherwise need to be turned off in AMP8.

Optioneering

We have consistently proposed best value solutions using rigorous optioneering. For more detail on our approach is provided within AFW08 Our Investment Development Process.

This has been conducted using the structured Risk and Value (R&V) process which is based on data and used to identify the best value solutions and/or opportunities.

The first phase of the R&V assessment is to fully determine the risks/opportunities for the service to our customers. Once a risk is fully defined, comprehensive root cause analysis is applied to determine the right source of the asset failures and the impact these have on the business. The next phase centres around solution optioneering which identifies alternative solution options, to mitigate/resolve identified risks and opportunities. The Whole Life Cost (WLC) and potential solution are evaluated using historic costs, and contractor/supply chain knowledge. The WLC is the total cost of owning and operating an asset over its lifetime. It is calculated by adding the initial capital expenditure (Capex) to the operating expenditure (Opex) over 25 years. Finally the solution options are evaluated using two important metrics: risk reduction and risk index.

Risk reduction measures the amount of risk that is removed by a proposed solution (i.e. initial risk minus percentage risk removed by solution option). Risk index measures the cost-effectiveness of a proposed solution (i.e. WLC of solution divided by residual risk). The lower the risk index the better; the solution with the lowest risk index is the best value option.

By utilising the key outputs from the R&V process the optimum solution can be identified and progressed. The stages and outputs from the R&V process are:

- Problem Definition Statement.
- Root Cause Analysis of identified risks.
- Unconstrained options – identification of any potential solution options to mitigate/resolve identified risks.
- Feasible options – selection of options to take forward based on practicality, efficacy, and affordability.
- Cost / Benefit ratios, or Risk Index, for each solution. The Risk Index is the Whole Life Cost of the solution divided by its risk reduction. The lower the risk index the better value the solution.

The schemes included in this business case have been monitored and assessed in line with the DWSP risk assessment process as described in the 'Project Development' section and have also been considered from a catchment management approach. Analysis of recent water quality data, along with the predicted future trends, as per the modelling graphs in the "Baseline Assessment" section in this document, has determined that monitoring and catchment management activity is not sufficient to mitigate the risk, and that further intervention is needed.

Selected Options

Do Nothing, Option 0

The "Do Nothing" option for the raw water deterioration sites results in turning each of them off for indefinite periods when shutdown trigger concentrations are reached. This will protect our customer's health but will affect the supply and demand balance and customer impact risk.

The R&V process does not provide a risk index for "Do Nothing" but rather a view of the Business Impact Score in terms of financial risk the business is exposed to by not implementing a solution to mitigate the identified risk.

Business Impact Costs of "Do Nothing"

Affinity Water	BUSINESS IMPACT COSTS: SUMMARY							
Only populate relevant green shaded cells						Broome Site Shutdown	Kingsdown Site Shutdown & Ineffective Blend	Stortford Resilience - Stansted Site Shutdown
MITIGATION OPEX								
Mitigation Opex cost per year £						£35,000	£224,389	£35,000
Supply & Demand								
Low Pressure	**No. Properties**							
	1to100	**~1,000**	**~10,000**	**~50,000**	**50, 000+**			
Cost per property £	8	6	3	3	3	£792,000	£990,000	£792,000
WATER QUALITY								
Water Quality General								
Compliance failures at water treatment works	Ml per day	£3,327				£399,240	£618,822	£399,240
Water Quality: Reports to DWI								
Preparation of 72hr report to DWI	Cost per report	£420				£16,800	£25,200	£16,800
Preparation of 20day report to DWI	Cost per report	£1,050				£42,000	£63,000	£42,000
Water Quality: Microbiological & Chemical	**No. Properties**							
	1to100	~1,000	~10,000	~50,000	50, 000+			
Biological or chemical contamination leading to major illness [over a 5day period] - £ per property	825	63	17	12	15	£4,488,000	£5,610,000	£4,488,000
CUSTOMER CONTACTS								
		Per Contact						
Unwanted phone contact		£3				£54,000	£19,800	£54,000
REPUTATION/ADVERSE PR								
		Per Incident						
Local residents		£112				£4,480	£6,720	£4,480
Local press & radio		£521				£20,840	£31,260	£20,840
Regional radio, press, television, national news		£1,042				£41,680	£62,520	£41,680
						£5,894,040	**£7,651,711**	**£5,894,040**

Figure 11. BIC Summary

Option Assessment:

All options assessed have the potential to reduce the nitrate concentration below the Affinity Water ideal limit of 43µg/l to protect our customers health.

Note that the assumed design flows Ml/d for each of the investments equates to the maximum output licence. These are as follows:

- Broome – 4.54 Ml/d
- Kingsdown – 3.7 Ml/d
- Stansted – 2.73 Ml/d plus blending flow* from Rochford Nurseries – 1.75Ml/d – Total = 4.46 Ml/d

* - Blending flow supplied via Rochford Nurseries booster pumps which are fed by Springwood Water Tower. The flow through the new main will be the metric measured in the PCD.

All options have been managed through the risk and value process to identify the best value option, based on lowest risk index (shown in Green), to mitigate the identified risk(s) and reduce the nitrate concentrations below the ideal limits of <43µg/l.

Broome

Option	Solution Option Description	Capex WLC	Opex WLC	WLC	Starting Risk Value	Residual Risk / Opp	Risk Reduction / Opp Attained	Risk Index
Solution								
1	Blending	£10,764,165.18	£75,000.00	£10,839,165.18	£5,894,040.00	£1,178,808.00	£4,715,232.00	2.299
2	Nitrates Plant (IONEX)	£7,219,730.57	£2,560,179.20	£9,779,909.77	£5,894,040.00	£0.00	£5,894,040.00	1.659
3	Nitrates Plant (ACWA)	£6,666,340.48	£3,146,755.85	£9,813,096.33	£5,894,040.00	£0.00	£5,894,040.00	1.665

Kingsdown

Option	Solution Option Description	Capex WLC	Opex WLC	WLC	Starting Risk Value	Residual Risk / Opp	Risk Reduction / Opp Attained	Risk Index
Solution								
1	Blending	£5,440,064.30	£75,000.00	£5,515,064.30	£7,651,710.90	£4,739,812.65	£2,911,898.25	1.89
2	Nitrates Plant (IONEX)	£7,219,730.57	£2,131,274.90	£9,351,005.47	£7,651,710.90	£0.00	£7,651,710.90	1.22
3	Nitrates Plant (ACWA)	£6,666,340.48	£2,735,860.75	£9,402,201.23	£7,651,710.90	£0.00	£7,651,710.90	1.23

Stortford Resilience (Stansted)

Option	Solution Option Description	Capex WLC	Opex WLC	WLC	Starting Risk Value	Residual Risk / Opp	Risk Reduction / Opp Attained	Risk Index
Solution								
1	Blending	£2,919,400.82	£75,000.00	£2,994,400.82	£4,043,554.10	£202,177.71	£3,841,376.40	0.78
2	Nitrates Plant (IONEX)	£5,423,797.33	£2,952,911.65	£8,376,708.98	£4,043,554.10	£0.00	£4,043,554.10	2.07
3	Nitrates Plant (ACWA)	£5,080,129.12	£3,473,817.75	£8,553,946.87	£4,043,554.10	£0.00	£4,043,554.10	2.12

Figure 12. Risk Indices for each site

Preferred, Best Value, Option 1

Broome – The nitrate plants are seen as better value than the blending option due to the length of main required and therefore the associated higher costs required. Both options have least residual risk with the IONEX plant identified as the preferred option, best risk index, due to lower Opex costs to run the nitrate plant.

Kingsdown – The nitrate plants are seen as better value than the blending option due to the length of main required and therefore the associated higher costs required. Both options have least residual risk with the IONEX plant identified as the preferred option, best risk index, due to lower Opex costs to run the nitrate plant.

Stortford Resilience (Stansted) – Blending has been identified as the best value option, with the best risk index, due to the short length of new pipework required and lower associated costs required to implement this solution. Furthermore, this option provides the additional benefit of providing resilience with an alternative contingency feed into the area via Forest Hall Road Booster.

This option does include a risk in that rising nitrate concentrations in the future could mean that site shutdown could occur with seasonal fluctuations of nitrate concentrations. However, with the introduction of the added resilience from the Forest Hill Booster this will ensure that the area is still supplied in the event Stansted WTW is shut down.

[redacted]

[redacted]

Figure 13. Schematic of proposed new pipework

Least Cost Option 2

Broome – In terms of Whole Life Cost the provision of an IONEX plant has been identified by the risk & value process as the least cost option.

Kingsdown – Option 1 blending main was the least cost option when optioneering commenced Summer 2022.

However, as of January 2023 nitrate results are much higher than previous results with current recorded & forecasted concentrations indicating that blending is no longer effective and therefore despite the costs this solution will no longer deliver nitrate concentrations below the safe limit resulting in continued site shutdowns. Option retained in this business case to show that blending has been considered.

Stortford Resilience (Stansted) – Option 1 Blending main is both the least cost & preferred option for this site as identified by the risk & value process.

Alternative Option 3

Broome - Option 1 blending main. Higher capex, lower opex, higher carbon. Relies on blend availability from Lye Oak, therefore reduced resilience.

Kingsdown - Option 1 Blending main – lower capex but relies on blend being available from St. Margarets which negatively impacts resilience and unplanned outage. It is also unable to provide sufficient blend all year round to meet the latest nitrate projections [March 23]. Highest carbon impact.

Stortford Resilience (Stansted) – Nitrate Plant, IONEX or ACWA, both plants are able to effectively remove nitrate concentrations to below 43 mg/l at the final water stage to meet compliance and the AW nitrate strategy. However, the disadvantage of utilising this option is that there is a high CAPEX cost involved to install the plant and significant increases in OPEX costs when in operation. Further to this, a run to waste or waste storage system would be required to manage waste from the ion-exchange plant.

Option Assessment Approach

Economic Assessment

An R&V was conducted for each site to identify the risks created by the presence of nitrates and the solutions available to mitigate these. Each option was costed using data from previous similar projects and vendor quotes where available. The efficacy of these solutions was then evaluated alongside the capital and operational costs within the R&V template to highlight the best value option based on Whole Life Costs (WLC) using the risk index.

A Net Present Value (NPV cost benefit analysis was conducted using an NPV period of 30 years, with a depreciation period of 45 years. Risk mitigation factors were applied to each option's NPV assessment directly, based on the most significant service impacts to the business that were identified from the relevant R&V.

Cost Estimation

Costs are developed using previous costs from AMP7 projects of similar scope & scale plus high-level estimates from vendors as and when required. Use of Unit Cost Database/Process models, provided by Motts McDonald which utilise actual cost data from anonymised companies with imbedded algorithms to factor for inflation and provide realistic 2023 pricing.

Confidence in the cost estimates for these schemes is medium to high, based on the comparable schemes recently delivered or still in delivery. These include Oughton Head Nitrate removal and Wheathampstead Ion exchange plant.

No allowance has been made for future inflation.

Benefit Estimation

Benefit is determined based on the R&V process where the value of the residual risk, on completion of the proposed works, is a factor in determining the most beneficial of the options considered.

In each case the benefit will be the ability to maintain supplies of wholesome water to customers which does not exceed the ideal limit of 43µg/l.

The Unplanned Outage PC is due to change in AMP8 and exemptions will no longer be made for WQ etc. The business impact costs [service measure framework] are being evaluated [March 2023] and there will be a direct cost attributed to all lost output due to unplanned outage. Forecasts are that Kingsdown will be impacted more than 50% of PWPC p.a., and Broome around 10%.

Efficiency

Broome - Removal of nitrates via a new treatment plant at Broome ensures maximum efficacy compared with blending which introduces a resilience risk where the loss of donor site(s) to blend the water results in also turning off Broome. The efficiency will be achieved by optimising the amount of water to be treated to guarantee sufficient nitrate reduction.

Kingsdown - Removal of nitrates via a new treatment plant ensures maximum efficacy compared with blending which introduces a resilience risk where the loss of donor site(s) to blend the water results in also turning off Kingsdown. The efficiency will be achieved by optimising the amount of water to be treated to guarantee sufficient nitrate reduction.

Current nitrate forecasts predict having to reduce output which would incur unplanned outage costs and a deterioration in resilience.

Stortford Resilience (Stansted) – Removal of nitrates via blending ensures that the nitrate concentration is reduced to below the ideal limit. Furthermore, this option also provides the additional benefit of providing resilience with an alternative contingency feed to the area using the Forest Hill Booster.

In the event nitrate concentrations increase beyond the capability of the blend to reduce the nitrate concentration below the ideal limit requiring the shutdown of the Stansted site the area will still be supplied by the newly introduced resilience via the Forest Hill Booster.

Assumptions Made

The lifespan of the options was assumed based on a combination of empirical average estimates and supplier information. This was applied to the R&V and the NPV assessments.

Sites have the spare electrical capacity to cater for the additional power required.

Any planning permissions as required will be granted.

Uncertainties and Sensitivity Analysis

Given that the NPV process was preceded by the R&V (Risk and Value) analysis conducted for each of the three sites respectively, the NPV assessments also served as a sensitivity analysis by effectively repeating the economic assessment elements of the R&Vs, to reinforce the outcome of the R&Vs while at the same time showing the practical financial benefits of the assessed investments to the business.

In addition, the following uncertainties also apply:

Costs subject to inflation – early placing of contracts with agreed framework prices to reduce risk of costs spiralling upwards.

New main routes subject to survey and change - costs build-up has factored in the demands that may accompany the highest-risk scenario, such as allowing for the cost of liaison with potential landowners in the event of easement requirements.

Supply chain – availability of components to build the solution within planned project timescales - use of framework agreements with early liaison with suppliers to ensure lead-times are factored into deployment plans.

Other Utility Company work plans – potential overlap of works creating potential delays - liaison with local council to advise of forthcoming works and agree window that these can be undertaken and also learn of other works planned at the earliest opportunity.

Significant increase in nitrate concentrations earlier than forecast accelerating the urgency of the proposed solutions - ongoing monitoring to highlight changes in concentrations at the earliest opportunity to enable plans to be revaluated as necessary.

Use of potassium chloride (KCl) as the regenerative solution for the proposed Nitrate Plants. The use of potassium chloride creates potassium nitrate (KNO3) as waste which is used as a common fertiliser. Although Affinity Water is exploring opportunities to trial this initiative, as it presents a good opportunity for a circular economy approach to this waste stream, there is currently no solution available to trial nor any planned dates. Cost estimates are for traditional solutions but as the potassium chloride solution matures and is available to test then this will be factored into any detailed design activities if timescales align.

We have made conservative estimates for when benefits will start and finish, and how they increase and decrease over time. As such, our economic analysis is inherently conservative by nature. We then consider the benefit metric for sensitivity studies as this becomes the most material uncertainty in the analysis. A sensitivity analysis was conducted as part of each CBA for the Nitrates sites, using the goal seek function within our spreadsheet to determine the value of a metric of concern that would be required to make the scheme cost beneficial. This provides a sensitivity check on the metric and enables commentary on the reasonableness of the economic analysis. We have run sensitivity checks on all significant benefit metrics.

In order to mitigate against project uncertainties and to avoid potential double-counting we have integrated of all of our infrastructure business cases with our over-arching network strategy to identify synergies and delivery efficiencies.

Carbon assessment

To facilitate an effective and efficient process to look at the implications of the PR24 Business Cases on carbon (operational and embedded) all Business cases were screened with relevant Business case leads to ascertain where there was potential for material impact on Carbon, Biodiversity or Natural Capital. Once the potential for an impact was identified the significance associated with that impact was explored with relevant specialists and business case leads.

Figure 14. High Level Schematic of the Carbon Assessment Process

Surgery sessions were held with business case leads to set out considerations for each of the three assessment areas. Criteria to assess significance of carbon impact included:

- A material increase or decrease in operational CO2 emissions and/or
- An impact on capital carbon, e.g. identification of requirement for a physical build or change in capital maintenance resource use

Both the embedded carbon (resulting from construction activities) and operational carbon (resulting from energy and chemical use) were assessed using Affinity Water's bespoke asset carbon estimation tool which includes over 400 different carbon models covering the types of below ground and above ground assets we typically construct and operate. The outputs of the carbon assessment (as tCO2e) can be seen below.

Carbon Tool Results

Total Whole Life Carbon (TCO2e) 40yrs	Broome	Kingsdown	Stansted
Blending	691	379	165
Nitrate Plant (IONEX)	140	139	138
Nitrate Plant (ACWA)	108	107	106

Figure 15. Table Showing Carbon Tool Output per Site

BNG assessment

BNG is derived from a metric created by Defra, which classifies types of habitats and their condition to give a unit score for a given site being worked on. UK Hab is the methodology that is used to classify the habitats and conditions within the metric, which is nationally used across the ecology industry.

Biodiversity Net Gain consideration has been calculated using the assessment tool provided by the Environmental Policy & Strategies team. This applies a representative percentage value to the Capex costs of each relevant solution option based on internal analysis. The percentage factor in this calculation varies depending on the Capex cost in question and the BNG classification of the site. This was then verified against previous similar project BNG costs where available, to ensure that the estimated costs were not an underestimate or greatly different from what would be expected. This assessment was completed for each scheme's preferred option and other viable options that required consideration of BNG, to form part of the selection process as per the following Figure 16.

Business Case	Scheme	AMP8 Capex (£)	Special Site / Habitat	Site %	Biodiversity Capex (£)	Notes
Raw Water Deterioration	Broome Nitrates - IONEX Plant	£ 4,809,327	N	1.0%	£ 48,093	Preferred Option
Raw Water Deterioration	Broome - Blending	£ 7,170,405	N	1.0%	£ 71,704	Option ruled out due to cost
Raw Water Deterioration	Broome - ACWA Plant	£ 4,440,694	N	1.0%	£ 44,407	Option ruled out due to higher Opex costs
Raw Water Deterioration	Kingsdown Nitrates - IONEX Plant	£ 4,809,327	N	1.0%	£ 48,093	Preferred Option
Raw Water Deterioration	Kingsdown Blending	£ 3,623,826	N	1.0%	£ 36,238	Option ruled out as no longer viable due to high Nitrate levels mean blend would still be above safe limit
Raw Water Deterioration	Kingsdown - ACWA Plant	£ 4,440,694	N	1.0%	£ 44,407	Option ruled out due to higher Opex costs
Raw Water Deterioration	Stortford Resilience Blending	£ 2,111,577	N	1.0%	£ 21,116	Preferred Option
Raw Water Deterioration	Stortford Resilience Nitrates - IONEX Plant	£ 3,922,985	N	1.0%	£ 39,230	Option ruled out due to higher cost
Raw Water Deterioration	Stortford Resilience Nitrates - ACWA Plant	£ 3,674,413	N	1.0%	£ 36,744	Option ruled out due to higher cost

Figure 16. Table from BNG Assessment Tool

Both Broome & Kingsdown are predominantly rural in nature with the agricultural land being highly arable and used mainly for winter wheat and rapeseed oil crops. Stansted Pumping Station (for Stortford Resilience) is situated in the residential area of the village Stansted Mountfitchett.

None of the sites are considered to be a site of special interest or habitat.

Third Party Assurance and Audit Trail

Liaison with AW Production and physical site visits form the basis of all individual site option requirements. Costs have been compiled and averaged/verified by multiple sources such as quotations, cost models and information from previous similar projects.

The Desktop R&V and NPV assessments have undergone similar internal governance and assurance processes, through regular review meetings with the Asset Planning Manager.

A full R&V workshop, with all key stakeholders will be held to review the risks and potential solutions using up to date data, followed up by site specific quotes from the vendors which will be used to gain financial approval to progress the solution.

Cost models are based on data from other businesses in the water industry which further strengthens the reliability of the data. The carbon model used is also based on ongoing information sharing with Motts MacDonald.

Option Assessment

Commentary on the Economic Assessment

An NPV (Net Present Value) analysis was conducted to assess the total value of the options proposed as investment opportunities to the business. Analysis was undertaken for the preferred option and least cost option for both Nitrate sites. These options were based on two types of Nitrate plants and blending to dilute the nitrate concentration.

The R&V (Risk and Value) initial analysis determines the best value option based on cost, residual risk and calculated whole life costs.

The effective good value options were then assessed using NPV.

The NPVs also served as a sensitivity analysis by effectively repeating the economic assessment elements of the R&Vs to reinforce their outcome while at the same time showing the practical financial benefits of the assessed investments to the business. A standard NPV period of 30 years was used, with a depreciation period of 45 years. Conversely to the R&V, the baseline option was not used as part of the final NPVs; rather, risk mitigation factors were applied to each option's NPV assessment directly, based on the most significant service impacts to the business that were identified from the relevant R&V.

NPV Output

Broome	Total NPV	Total NPV Benefits	Benefit / Cost
IONEX Nitrate Removal Plant	£1.9M	£7.3M	1.34
ACWA Nitrate Removal Plant	£893K	£3.7M	1.16
Blending	£900K	£6.6M	1.16

Kingsdown	Total NPV	Total NPV Benefits	Benefit / Cost
IONEX Nitrate Removal Plant	£2.7M	£8.5M	1.48
ACWA Nitrate Removal Plant	2.6M	£8.5M	1.46
Blending	£2.0M	£5.5M	1.64

Stortford Resilience	Total NPV	Total NPV Benefits	Benefit / Cost
IONEX Nitrate Removal Plant	£2.5M	£2.8M	0.53
ACWA Nitrate Removal Plant	£2.6M	£2.8M	0.52
Blending	£3.4M	£5.3M	2.84

Figure 17. NPV Summary from the Cost Benefit Analysis Spreadsheets for each Site

Preferred, Best Value, Option

For both Broome & Kingsdown the IONEX Plant is the preferred option to lower nitrate concentrations beneath the ideal limit of <43µg/l and enable the business to adhere to the regulatory obligation to provide wholesome water to our customers.

Furthermore, this option is more resilient as there is no dependency on a secondary site to provide the additional water required to deliver the blend to dilute the nitrate concentration. This option also benefits from lower Opex costs than an ACWA plant and has the lowest carbon footprint of the options.

With the high concentrations at Kingsdown resulting in the site being offline for extended periods, usually several months at a time, and with levels continuing to rise at Broome, it is preferable that the solution is urgently progressed as extended delays would only increase the implementation costs. The economic assessments at both sites demonstrate this by factoring in the assumption of a five-year delay and a corresponding 10% cost increase including the import costs from Southern Water. This analysis also includes loss of site output capacity (based on the capacity of the sites), using Ofwat values (£'s) and applying a risk factor that is dependent on the solution.

For Stortford Resilience, the preferred solution is to provide a blend using the flows from Stansted and Rochford Nurseries with Forest Hall Booster being available to mitigate poor pressures in the area during periods of peak demand if required. In the event of nitrate concentrations at Stansted being too high to make the blend effective, the Stansted PS can be shutdown with the area continuing to be supplied by the Forest Hall Booster.

This Blending option has lower Capex than the installation of a Nitrate Plant, due to the shorter length of main required to the similar options for Broome & Kingsdown. Additionally, this option has lower ongoing Opex costs too.

Additional benefits to the business include the avoidance of regulatory penalties, reputation decline and reduced risk of a reduction in CRI (Compliance Risk Index) performance.

All the above options have received accelerated funding with Broome & Kingsdown detailed designs & contract placement being undertaken in Year 4 & 5 ready for works to commence in Year 1 of AMP8. For Stortford Resilience works are planned to be completed prior to AMP8.

Least Cost Option

Broome – the ACWA Nitrate removal plant is the least cost option from a Capex perspective but due to higher Opex costs has been ruled out in favour of the IONEX plant.

Kingsdown - With the increasing nitrate concentrations the Blending option is no longer viable as the combined peak output of both sites would be insufficient to dilute the nitrate concentrations below the safe level. Furthermore, in the event of a shut down at the Blend site, St Margarets, Kingsdown would also need to be shut down due to the high concentration of nitrates present to prevent this unwholesome water from entering supply.

Stortford Resilience – the preferred option of blending is also the least cost option.

Alternative Option 1

Broome – the provision of a main to Blend at Chalksole Reservoir has been discounted as this is the most expensive option and has the highest embedded carbon of the three options available. Additionally, this solution requires Lye Oak to be fully operational and in the event of unplanned, or planned, outages then the only supply into Chalksole Reservoir would be via Broome with nitrate concentrations above the safe limit. Longer term if nitrate concentrations continue to rise then the peak output from both sites may be insufficient to dilute the nitrate concentrations back to within the safe limit.

Kingsdown - the ACWA Nitrate removal plant is the least cost option from a CAPEX perspective but due to higher OPEX costs has been ruled out in favour of the IONEX plant.

Stortford Resilience – provision of a Nitrate plant, IONEX or ACWA, has been ruled out due to higher capex & opex costs.

Meeting Affinity Water's Outcomes

The requirement for this investment is to meet the commitments set out in our Strategic Direction Statement to "Deliver what our customers need, ensuring affordability for all," which encompasses "Exceed[ing] customers' expectations for drinking water," and to "Be prepared for change and resilient to shocks and stresses".

The primary performance commitment relevant to this business case is CRI (compliance risk index). By investing in treatment/blending solutions we are ensuring that we are safeguarding water quality for our consumers, now and in the future, in the most cost-efficient way.

The secondary performance commitment linked to this business case is unplanned outage, as a water treatment works will be turned off and taken out of operation if the nitrate concentrations are too high for us to be able to adequately ensure we can meet water quality regulations at customer properties.

Justification of the Preferred Options

Broome – The installation of an IONEX Nitrate plant on site enables the localised reduction of the nitrate concentration in the raw water to below the safe limit. Based on the R&V and NPV studies this is the best value option as it mitigates more of the risk and is not dependent on the operational status of Lye Oak to provide the Blend at Chalksole Reservoir to dilute the nitrate concentration. Finally, the IONEX plant has lower OPEX cost to the ACWA plant.

Kingsdown – The installation of an IONEX Nitrate plant on site enables the localised reduction of the nitrate concentration in the raw water to below the safe limit. Based on the R&V and NPV studies this is the best value option as it mitigates more of the risk and is not dependent on the operational status of St Margarets to provide the Blend to dilute the nitrate concentration. Additionally latest sample data shows that the nitrate concentration has now increased beyond the peak capability of both sites to dilute the concentration to within the safe limit. Finally, the IONEX plant has lower OPEX cost to the ACWA plant.

Stortford Resilience – The provision of a blend via Rochford nurseries with the addition of contingency back-up via the Forest Hall booster is the lowest cost option in terms of Capex & Opex. Additionally, this option is less dependent on the secondary site at Rochford Nurseries to provide the blend as the area can still be blended via the Forest Hall Booster.

Delivery Considerations

Related Projects

Oughton Head Nitrate removal plant.

Wheathampstead chromium VI specific Ion Exchange plant.

Above projects are funded through AMP7 with no funding overlap with the projects at the three sites in this document requesting AMP8 funding.

Lessons Learnt

New main routes – engineering difficulties, risk to time and costs.

DWI Reg 31 timescales for approval needed for new resins.

Additional benefits related to other emerging contaminants.

Delivery Risk Management

Recent experience gained through delivery of similar schemes gives confidence in the time, costs, and specification required for these projects. Aside from this, any other project risks will be dealt with using the normal project life-cycle processes and the framework supply chain.

Once a project manager has been appointed to each project, they will manage the project delivery and associated risks for implementation. These will include the activities listed below which may increase as the detailed planning progresses and further risks are identified.

- Project Delivery – agreeing & monitoring of construction programme & timescales with vendors and associated supply chain management.
- Buildability
    - Flows meet blending requirements to reduce nitrate concentrations below the ideal limit of <43µg/l & still provides satisfactory pressure for our customers.
    - Nitrate plant design reduces concentrations to below the ideal limit of <43µg/l & maintains a satisfactory level of service for our customers.
- Controls & Telemetry.

- Water Quality – ensure new solution is safe for customers prior to entering service and ensure that ongoing monitoring is in place to ensure customers are protected.
- Health & Safety – detailed assessments will be taken and highlight any additional risks such as working by railway lines.
- Roadworks – liaison with the local authority for other utility work plans in the area, obtaining permits to work and ensure resurfacing plans are completed.
- Planning permissions – obtaining required permissions for new buildings to house the Nitrate Plants.

Further detail regarding how we have ensured the deliverability of our full investment portfolio is provided within AFW 32 Deliverability of our Plans.

Monitoring and Reporting of Benefits

Once the new solution is in place at each site, tested to validate the required reduction in nitrate concentrations and successfully commissioned the Water Quality (WQ) Team will provide ongoing sampling to ensure that the nitrate concentration remains below the AW target level <43 mg/l (set due to the +/- 3 mg/l measurement error so that the concentration in the final water remains below 47 mg/l).

Ongoing monitoring of site availability against PWPC as business as usual.

Supporting Information

Graph (Figure 18) below shows nitrate concentrations following blending Kingsdown with St. Margarets. Black line shows concentrations based on actual data with recent spike in concentrations at the end of 2022 clearly visible and why blending has been discounted as a viable option due to blend being unable to bring the level below the DWI Safe Limit of 50 mg/l.

The grey line has been overlayed to provide a view of how these increased concentrations could have affected the blend historically and highlights the increased number of breaches over the DWI safe limit.

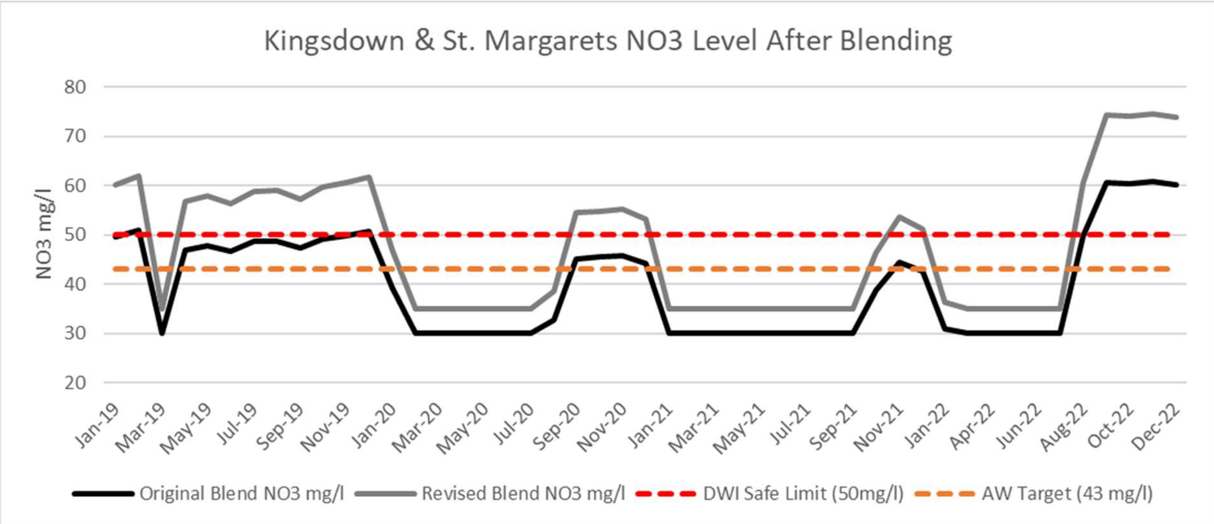

Figure 18. High Level View of Nitrate Concentrations after Blending

Affinity Water

Lead Programme

August 2023

Contents

Summary

Lead in drinking water at any concentration is a known health issue. World Health Organisation (WHO) and European Food Safety Authority (EFSA) agree that there is no safe lower limit of lead that should be in water supplies. Health effects are varied but most are acutely felt by small children (including unborn babies) at even low-level concentrations, with adverse effects on adults also observed.

This evidence has driven the initial phase of an ongoing reduction in the lead water quality standard within the EU Drinking Water Directive, lowering it from 10 to 5 µg/l.

This business case is driven by a statutory duty to uphold water quality standards regarding lead, and our ambition to go beyond the regulatory requirement aligning with the Drinking Water Inspectorate's (DWI's) ambition of achieving a lead-free society. Our Lead Long-Term Delivery Strategy (LTDS) ambition is to remove all lead supply and communication pipes from customer properties in our 11 highest risk water supply zones (WSZs) by 2050.

The proposed AMP8 enhancement investment will serve as a vital step in our journey. It considers customer feedback and addresses the balance between costs, benefits, and the significant challenge of removing all lead pipes.

Our proposed enhancement investments for AMP8 will include the following enhanced activities:

- Replacing or refurbishing communication pipes where samples have a lead concentration of 5-10 µg/l and offering to replace or refurbish the supply pipe where the property owners consent to the work being carried out.

- A small-scale innovation trial in one of our high-risk water supply zones seeking to drive unit cost reductions and targeted approach on properties where the pipework configurations pose difficulties using existing methods. The number of pipes to be replaced or refurbished is estimated at 500.

- The trial will align with wider industry trials considering solutions to 'complex supply layout' renewals, such as properties with shared supplies, houses converted to flats and managing tenanted properties.

The requirement for this investment is to meet the commitments set out in our Strategic Direction Statement to "Deliver what our customers need, ensuring affordability for all" and "Exceed customers' expectations for drinking water."

Affinity Water

Project Details

AMP8 Spend	2025-26	2026-27	2027-28	2028-29	2029-30	Total
Capex (£m)	0.41	0.81	1.00	0.99	0.79	**4.00**
Opex (£m)	0.00	0.00	0.00	0.00	0.00	**0.00**
Totex (£m)	0.41	0.81	1.00	0.99	0.79	**4.00**

Drivers	
56%	Lead communication pipes replaced or relined
22%	External lead supply pipes replaced or relined
22%	Internal lead supply pipes replaced or relined

Benefits
Lead Health Improvements (properties)

Economic Analysis			
NPV Costs (£m) (2025-55)	**3.2**	NPV Benefits (£m) (2025-55)	**3.5**
NPV (£m) (2025-55)	**0.3**	Benefit / Cost Ratio	**1.1**

Six Capitals

Natural	Social	Financial	Manufact.	Human	Intellectual
	★ ★ ★		★ ★		★

Project Description

This business case is driven by a statutory duty to maintain potable water quality in the context of lead standard improvements and our ambition to surpass regulatory requirements, supporting the Drinking Water Inspectorate's (DWI's) ambition of achieving a lead-free society. Our Lead Long-Term Delivery Strategy (LTDS) ambition is to remove all lead supply and communication pipes from customer properties in our 11 highest risk water supply zones (WSZs) by 2050, estimated to be approximately 76,000 pipes, 25% of the remaining lead within our network.

The enhancement investment proposed for AMP8 will result in a critical steppingstone to support our journey, whilst taking account of customer views and balancing the costs, benefits and significant deliverability challenge associated with removing all lead pipes.

Our proposed enhancement investments for AMP8 will include the following enhanced activities:

- Replacing or refurbishing communication pipes where samples have a lead concentration of 5-10 µg/l and offering to replace or refurbish the supply pipe where the property owners consent to the work being carried out.

- Supply pipe replacement or refurbishment will be offered up to the properties' internal stop valves as the preferred option. A secondary option would be to the building's curtilage (Point of Entry (P.o.E)), as the customer is the supply pipe owner, they reserve the right to refuse work on their lead supply pipe.

- We will conduct a small-scale innovation trial in a high-risk water supply zone, aligned to Ofwat's wider approach. Our goal is to reduce unit costs and target properties where the pipework configurations pose difficulties to the current lead pipe replacement or refurbishing methods. We have estimated the number of pipes to be replaced or refurbished as part of this trial at 500, although the number may vary depending on the unit cost of the replacements.

- The trial will focus on conducting research into innovative techniques to identify or replace lead pipe in challenging installations, as well as novel ways of delivering pipe replacements within customer properties. The trial aims to identify ways to reduce the overall unit rate costs of lead communication and supply pipe replacements or refurbishing at wholescale. This seeks to improve the overall marginal cost benefit of renewing lead for 'average properties' and thereby justify wider scale lead activity in future AMPs.

- The trial will also align with wider industry trials planning to consider solutions to 'complex supply layout' service pipe renewals, such as properties with shared supplies, houses converted to flats and managing tenanted properties. The trial aims to collaborate with aligned water companies in this development area.

- We will maintain our investment in Base activities to meet our statutory requirements. Our reactive Base investment to reduce the lead exposure through drinking water will continue to include replacing or refurbishing communication pipes at properties where random daytime samples have a lead concentration >10 µg/l and replace or refurbish the supply pipe where the property owners' consent to the work being carried out. We forecast this Base expenditure activity will average around 50 properties per year. We will also continue to replace lead communication pipes at the properties owners request where they have already replaced their lead supply pipe.

There is no overlap with the funding for Enhancement activities as the criterion of lead concentration at the customer tap will be used to determine which program the funding will come from. There is no overlap or duplication with activities funded at previous price reviews as all properties at which lead will be removed in AMP8 have had no lead removed by us previously.

Other non-reactive Base activity will also continue during AMP8 including:

- Continuing to monitor the efficacy and consistency of orthophosphoric dosing systems to reduce the plumbosolvency of our water supplies within defined areas.

- Liaise with public health teams and local authorities to promote benefits of lead pipe replacement / refurbishment across social housing sector and vulnerable groups.

- Actively promote the benefits of replacement / refurbishment of lead supply pipes across all communities and with NHH Retailers.

The requirement for this investment is to meet the commitments set out in our Strategic Direction Statement to "Deliver what our customers need, ensuring affordability for all," which encompasses "Exceed[ing] customers' expectations for drinking water," and to "Be prepared for change and resilient to shocks and stresses".

Project Development

Baseline Assessment

Lead in drinking water at any concentration is a known health issue. World Health Organisation (WHO) and European Food Safety Authority (EFSA) agree that there is no safe lower limit of lead that should be in water supplies. Health effects are varied but most are acutely felt by small children (including unborn babies) as exposure to even low-level concentrations of lead is known to inhibit brain development. In adults it may impair kidney, heart, and circulatory system health. Adverse health effects from ingestion of drinking water which contains even very small amounts of lead cannot be ruled out. This evidence has driven the first step in what will be a continuous decrease over time in the regulatory limit in the lead water quality standard, from 10 µg/l to 5 µg/l in the current recast of the EU Drinking Water Directive[1].

The point of compliance measurement for lead is at the consumer's tap, and action is mandatory in response to every analytical result that exceeds the current prescribed concentration or value (PCV) 10 µg/l standard to protect consumers.

Since 2002, we have carried out enhanced sampling for lead in water supplies at properties within our supply area. Data from our sampling program has provided a clear understanding of our high and low-risk areas for lead. This data has been crucial in shaping our lead pipe replacement plans for AMP6 and AMP7.We have used this information to frame our proposals for AMP8.

Table 1 displays our highest-risk WSZs, identified through historical and recent lead sample results showing elevated lead pipe concentrations. We've completed lead replacement programs in shaded WSZs, leaving 11 WSZs pending.

Table 1. Our highest-risk water supply zones

Water Supply Zone	Zone Description	Comments
42	Chesham/Bovingdon	
44	Beaconsfield/Chalfont St Giles	
45	Chorleywood/Gerrards Cross	
46	Watford	Targeted lining or replacement of lead communication pipes completed during AMP6
51	East Barnet	
52	Stanmore/Mill Hill	
53	Edgeware	
54	Finchley	Targeted lining or replacement of lead communication pipes completed during AMP6
56	Harrow	
57	Colindale/Kingsbury	
75	Underground Zone 1 was ZUN1	
79	Folkestone and Hythe	
83	Belmont	

[1] Drinking Water Directive

Across our supply area, we demonstrate high compliance with the 10 µg/l limit through existing plumbosolvency control targeting our 'high-risk' WSZs. In cases where a sample exceeds 10 µg/l, and we confirm that the communication pipe is lead, we replace it with a more suitable material at no cost to the customer. Since July 2021 we have taken the proactive approach of replacing communication pipes where sample results are >5 µg/l.

In February 2021, DWI issued research on long-term strategies to reduce lead exposure from drinking water[2]. One of the key findings, based on available scientific and practitioner evidence, concluded that water companies will be required to replace lead supply pipes in addition to communication pipes to guarantee compliance with a lower regulatory standard for lead at the consumer tap of 5 µg/l or lower.

Another conclusion from the research was that, while lining technologies do provide the potential for quicker and more efficient application (less excavation; lining can be applied from the ferrule or external stop tap to the internal stop tap in one operation), there is a lack of evidence to assess the longevity of relining approaches for maintaining the level of protection required (Tarbet, et al., 1999) (Lynn, et al., 2012). The design life of lining materials may be a few decades and therefore further regular, though infrequent, interventions would be required to ensure lead exposure continues to be minimised. Each intervention risks further exposure to consumers from lead in the host pipe and is therefore undesirable as a long-term solution.

In their long-term planning guidance for PR24[3], DWI stated that "reducing the risk of lead in drinking water should remain a priority" and "companies should be ambitious in their long-term lead strategies and continue to plan and invest in reduction of lead exposure through drinking water."

The Defra Strategic Policy Statement (SPS)[4] to Ofwat supports action by industry to trial approaches to reducing exposure of lead to customers from drinking water, from a public health perspective. It is therefore expected that companies should investigate and develop trial projects to better understand how they can deliver further reductions on lead in drinking water effectively and efficiently. We have been involved in wider industry planning and design of the cross-industry trials which will see the whole industry work collaboratively on the design and reach of proposed AMP8 trials to minimise duplication and maximise information gathering at lowest whole industry level cost.

The research and guidance are not policy statements but clearly indicate the ambition and direction required to deliver public health improvements. There are also more fundamental questions raised over government and stakeholder support, the cost benefit analysis models, ownership of supply pipes and societal willingness to pay.

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2 Long-term Strategies to Reduce Lead Exposure from Drinking Water Report Reference DWI14372 2 Jan 2021

3 Price review process - Drinking Water Inspectorate

4 February 2022 The government's strategic priorities for Ofwat GOV.UK

The largest proportion of lead material is present as supply pipes (that run from the property boundary to the internal stop valve) and communication pipes (the pipes that run from our water mains to the property boundary). We estimate there are approximately 312,000 lead communication and supply pipes in our region; at the current unit price, it would cost around £1.3bn to replace all of these. The number of properties with lead in our high-risk areas number approximately 76,000.

Whilst we have started to remove lead from our network, significant numbers of lead pipes remain; since 2000, we have replaced or relined approximately 68,200 communication pipes (some including supply pipes) which comprise 18% of the total number in place in 2000. We spent £24m on our proactive lead programmes in AMPs 6 and 7. We have spent approximately £1.7m per year on reactive replacements since 2011.

Problem Statement and Stated Need / Driver

There are approximately 312,000 properties in our region where customers could be exposed to lead in their drinking water through the presence of lead pipes.

World Health Organisation (WHO) and European Food Safety Authority (EFSA) agree that there is no safe lower limit of lead that should be in water supplies. Given the latest advice, the present recast of the EU Drinking Water Directive proposes reducing the drinking water standard for lead to 5 µg/l within the next decade.

Lead pipes are known for their extended durability without fracture or failure, which is why they have not been widely replaced merely due to the end of their serviceable life. Therefore, only proactive replacement of them will see a significant reduction in their presence in the short to medium term.

Risks, Issues and Requirements

Phosphate availability

Plumbosolvency control, crucial for achieving the 10 µg/l limit, relies on orthophosphoric acid, which is a finite resource. During AMP7, we witnessed an 89% price increase for orthophosphoric acid between Q4 2021 and Q4 2022 from our supply chain. Anecdotal evidence from cross-industry working groups (e.g., Water UK and UKWIR) suggests that this trend of rising costs and sourcing difficulties is likely to persist.

While there may be another 50+ years of phosphate supply available globally for water treatment, it is prudent to mitigate this risk by gradually reducing our reliance on it before we face supply shortages.

Legislative change

Water companies have no powers of enforcement over lead supply pipe replacement. Renewing or partially renewing supply pipe is only possible with the property owners' explicit consent. Even in street-by-street renewal programmes offering free supply pipe renewal to the customer, 100% take up for supply pipe renewal is unlikely. Therefore, the successful removal of 100% of lead supply pipes will require multiple passes through the street that may take decades to achieve.

Legislative change around ownership of customer supply pipes, such as water company adoption of them, will materially change our lead programme as it will remove the risk associated with customers refusing permission for us to replace their supply pipe at the same time as their communication pipe. Other legislative changes, such as requiring customers to replace lead pipes prior to property sale, would also assist with our strategy.

Innovation

Innovation may provide partial solutions, but a current horizon scan suggests relatively few potential solutions in development, at any stage of technological readiness, that would materially change our required funding or approach.

Supply chain

The ability for existing supply chains to meet a nationwide response to a 5 μg/l permissible lead limit is a concern. We have run small scale trials in AMP7 to understand better the challenges in renewing both company and customer owned lead assets to meet a potential 5 μg/l standard. This has shown that, at small scale, a working methodology to renew customer supply pipes can be made workable. Further research may be needed to determine a delivery approach in more challenging scenarios such as shared supplies.

Allocation of Costs

The delivery of this scheme is driven by a requirement to maintain potable water quality in the context of lead standard improvements and our ambition is to go beyond the regulatory requirement supporting the Drinking Water Inspectorate's (DWI's) ambition of achieving a lead-free society.

Our proposed enhancement activities, as outlined in Project Description, will result in a step-change in the service level provided to consumers and is therefore Enhancement expenditure. Extensive Base activity, also outlined in that section, will continue in parallel.

While similar in nature, there is no overlap between the Base and Enhancement programs of investment as the criterion of lead concentration at the customer tap will be used to determine which program the funding will come from.

DPC

This scheme is not suitable to be considered for a Direct Procurement for Customers approach as the value is significantly below the £200m TOTEX threshold.

Research, Pilots, and Technology Development

Our AMP6 and AMP7 Lead programmes have both been instrumental in the development of our planned activity.

In AMP6 we undertook communications pipe replacement schemes in two of our high-risk WSZ; Watford and Barnet, London. We assessed over 37,000 properties and determined through a desk-top study that, of these, 18,000 potentially comprised lead pipes. We investigated these 18,000 further using trial holes and, of these, 12,000 lead renewals were undertaken and a further 6,000 confirmed as "non-lead" from trial hole excavation. This work identified appropriate working methodologies for street-by-street activity in busy urban areas and methods of working to renew ferrules in the water main plus workarounds for various challenges. The programme was also used as an innovation test bed, trialling activities such as pipe lining and use of Arctic Driver, a tool for replacing ferrules under pressure via over-clamping.

In AMP7 we trialled the replacement of the full-service pipe from ferrule to customer Internal Stop Valve (ISV). This activity in our East area initially focussed on developing the proof of concept for the work, developing a working methodology for engaging with customer side pipe renewal and generating a tolerable customer experience journey.

From this activity, we obtained data regarding costs and uptake rates. In Phase 1 of the trial, we provided free supply pipe replacement, and approximately 85% of eligible properties took up the offer. Among them 96% (24 customers) chose replacement from stop tap to internal stop valve, while only 4% (1 customer) opted for replacement up to point of entry.

The findings were found to be substantially higher than other water company trials of similar activity to date. During the phase 2 trial customers in a similar trial area to phase 1 were asked to pay between £883 and £1,873 for the supply pipe renewal (depending on length and whether replacement was to point of entry or internal stop value), take-up was very low at around 2% of the eligible properties, all of whom opted for replacement to internal stop valve.

Work has been undertaken to identify the financial benefits to health of removing lead pipework from properties. This was a development of the DWI research paper published in 2021[5]. The authors of the paper were engaged, and further activity undertaken to reach a financial benefit understanding to households' health of no

[5] DWI (2021) Long-term Strategies to Reduce Lead Exposure from Drinking Water, DWI1372.2, 26 January 2021

longer being exposed to lead through the removal of just the communication pipe, and removal of the communication and supply pipe. An average one-off benefit figure of £2,400 when the lead communications pipe is removed and £3,839 when the whole lead communication and supply pipe is removed was determined. These values apply to an average household. The benefits are greater where the residents of the property are more vulnerable to lead, either due to young age or due to already suffering from selected kidney and heart conditions.

Customer Engagement

Detail of Customer Engagement work

We have undertaken extensive engagement with our customers to build a detailed understanding of their priorities and reflected these in this business case. For more detail on our customer engagement see AFW04 What Customers and Stakeholders Want.

We have engaged extensively with our customers through the process of developing our PR24 business plan[6,7,8,9,10].

We carried out customer engagement as part of the Strategic Resource Options programme of work, looking at how customers preferred to be communicated with. This gave us the opportunity to gain insights into their thoughts and preferences about several of the long-term plans related to water resourcing, including source types.

An evidence review was carried out of 50 documents and stakeholder interviews with each of the water companies, with documents gathered directly from the 6 water companies involved in WRSE, and the evidence was then synthesised to identify consistent findings which were triangulated to assess their strength. During the qualitative phase we tested these findings with 96 household customers across the 6 companies, including Gen Z and vulnerable customer. During the quantitative phase we held 15-minute online surveys with 1,762 household and 198 non-household customers for robust segmentation and validation of findings.

This research reinforced our understanding that water is a topic of low awareness and understanding among our customers. This in part is driven by general satisfaction with the customer experience of water in terms of taste, smell and hardness.

We followed this up with some deep dive sessions in July 2022 to specifically test on our own long-term plans with a wide cross section of our customer base. 82

[6] WRSE Customer Preferences Part A Evidence Review Final Report eftec ICS February 2021.pdf
[7] Water Club - Changes of Source - June 2022.pdf
[8] Affinity Water Customer Valuation Research Summary Report May 2023.pdf
[9] Affinity Water Customer Priorities for Long-term Ambitions, May 2023
[10] 'Customer Priorities for long-term ambitions to support PR24 and long-term delivery strategies,' September 2022

customers and 10 business representatives participated in this research. Customers were divided into 'household', 'vulnerable' and 'future' groups to reflect a range of views, whilst local business representatives provided views on behalf of their place of work ('Non-household').

The Non-household representatives were recruited from businesses which are heavy water users. Customer groups covered a range of ages, socio-economic backgrounds, and areas within Affinity Water's region to enable a diverse range of views. Given the long-term focus of the research, future customers were also included to gauge an understanding of priorities from individuals who are likely to become Affinity Water customers in the future.

Ten online focus groups were held (household and future customers) and fifteen one-to-one interviews (vulnerable and non-household customers). Focus groups were held via online video, using the specialist VisionsLive platform, each session lasting 90 minutes. Voting exercises and activities were used throughout the focus groups, to aid engagement, capture strength of feeling, and focus the discussion on the core research questions. These were qualitative sessions, and the outcomes provided insight into customer views of the relative importance to them of various considerations.

Finally, we carried out some detailed quantitative research through a mix of online and in-person interviews in October – December 2022. The approach featured a representative sample of approximately 900 household customers and 300 non-household customers. The household sample included 104 "digitally disengaged" customers to ensure full participation across the customer base.

The overall survey included questions on: (a) overall priorities for water services; (b) awareness and perceptions of the individual investment areas (reducing abstraction/environmental restoration, carbon net zero, improving resilience, lead replacement, and hard water); and (c) preferences for level of investment in each area for the period 2025 - 2050.

The research was based around alternative planning scenarios for each of the five investment areas. Scenarios were described in terms of the target outcomes and associated bill impact profile for the required pacing and timing of investment to meet those outcomes. Scenario descriptions were proceeded by explanatory information that summarised the current situation, what could be improved through an enhanced programme of investment, the potential outcomes (benefits) and the potential drawbacks.

Respondents were asked to select their (most) preferred scenario for each investment area from a set of three (essentially: "lower", "intermediate", and "higher" investment scenarios). Respondents were offered the opportunity to adjust their choice of preferred scenario in each investment area once they had the overall view of level of ambition and associated total bill impact over 25 years.

Evidence of Customer Preferences

We have developed all this research and analysis into a document called 'What our Customers & Stakeholders Want[11]' which presents the findings from the various customer engagement activities. The key takeaway point from the research is that customers have a high level of inherent trust in us as a water provider, and generally are happy for us to make decisions about technology selection and water quality risk management without consultation with them – we are the experts, and they trust us to make those decisions.

Another outcome of the research was a strong steer that customers expect us to meet our regulatory duties at all times, with respect to the Water Supply (Water Quality) Regulations. Any strategic decisions we make with respect to cost or carbon emission reduction must not have any detrimental impact on water quality performance.

Out of the five key investment areas explored in the quantitative research, lead pipe replacement ranked as the highest priority. 48% of participants in the study opted for the highest possible level of investment when allocating spend to the different investment areas. This insight conflicts with previous research from 2021, which showed a much lower level of awareness and concern; this could be due to the previous survey being qualitative and not representative[12].

The qualitative research sessions indicated that customers were generally observed to be more sensitive to avoiding deteriorated service levels compared to the preference for improvements. Household customer values for improved service levels for areas including tap water aesthetics was relatively modest – but nevertheless improvement in these areas was viewed as beneficial. In general, there was a limited preference for changes in service levels for hard water and hosepipes bans. Respondents felt that Affinity Water's services are good value for money and were generally satisfied with the services they receive.

Customer protection

We have discussed our lead replacement strategies, both for AMP8 and the longer term, with the DWI. They are supportive of our approach.

We will develop a PCD to cover this program that will safeguard delivery of all the customer benefits highlighted in this business case. Our PCD will cover all properties that will be included in the enhancement work and hence all the benefits per property will be included.

Note that there is no third-party funding arrangement related to this programme of work.

[11] What our Customers and Stakeholders Want V5 final.pdf
[12] Report 125 - Lead Pipe Replacement 1 Customer research Stage 1 interim report, Blue Marble 10/06/21

Partnering

Collaboration and Partnering

Engagement with Stakeholders and Partners

- Industry collaboration

Within the industry we are an active contributor to the UK Lead steering group who act as a body of contacts to engage the regulators (specifically DWI, and Ofwat, facilitated by Water UK) about our plans and to gain feedback from them with regards to industry direction.

An Affinity Water representative led the 'Innovation working group' for several years, sharing our expertise and knowledge gained through our industry leading innovative AMP6 and AMP7 programmes. This group is looking for new and innovative approaches to delivering lead activity into the future. Under our leadership the group undertook a Knowledge Transfer Network cross industry challenge to identify new and innovative approaches to lead service pipe renewal. No viable options for immediate deployment were identified.

- DEFRA (Department for Environment Food and Rural Affairs)

Accelerated Infrastructure Programme Opportunity – In October 2022, Defra asked water companies to propose schemes for accelerated additional infrastructure delivery in 2023-24 and 2024-25 that would provide benefits for customers, communities, and the environment. Completion of planning permission, detailed design, and delivery contracts were proposed for both Kingsdown and Broome WTW nitrate schemes and submitted our draft business case to the DWI. In April 2023, Ofwat's draft decision supported the acceleration of both schemes proposed.

- Drinking Water Inspectorate (DWI)

We were invited by the DWI to carry out some early engagement with representatives from the regulator through the Autumn of 2022. We met with them during November 2022 and shared an early view of what is likely to be included in the water quality programme for PR24, their initial feedback was supportive of our proposals.

In January 2023 we submitted a summary statement to the DWI which highlights significant new future risk mitigation measures that we will be seeking support for in the PR24 proposals. The purpose of this statement is to:

  - to understand the justification and evidence for proposals
  - to estimate the number and type of submissions to expect

In addition to the summary paper, in March 2023 we submitted to DWI our draft business cases for drinking water quality investments.

- Environment Agency (EA)

We have liaised closely with the EA to develop our WINEP and catchment management plans for PR24, and have taken a holistic approach at an Operational Catchment scale, incorporating:

  - Sustainability reductions (SR's)
  - Abstraction Impact Assessments
  - Biodiversity enhancement
  - Catchment and Nature-based solutions (C&NBS)
    - Revitalising Chalk Rivers - River restoration, habitat enhancement and monitoring
    - Resilient Chalk Catchments - Catchment management measures for multiple benefits (water resources, water quality, biodiversity, carbon, chalk stream resilience)
  - Flagship Chalk Stream Catchment Restoration projects (CaBA strategy)

The engagement process is outlined in the schematic (Figure 1) below.

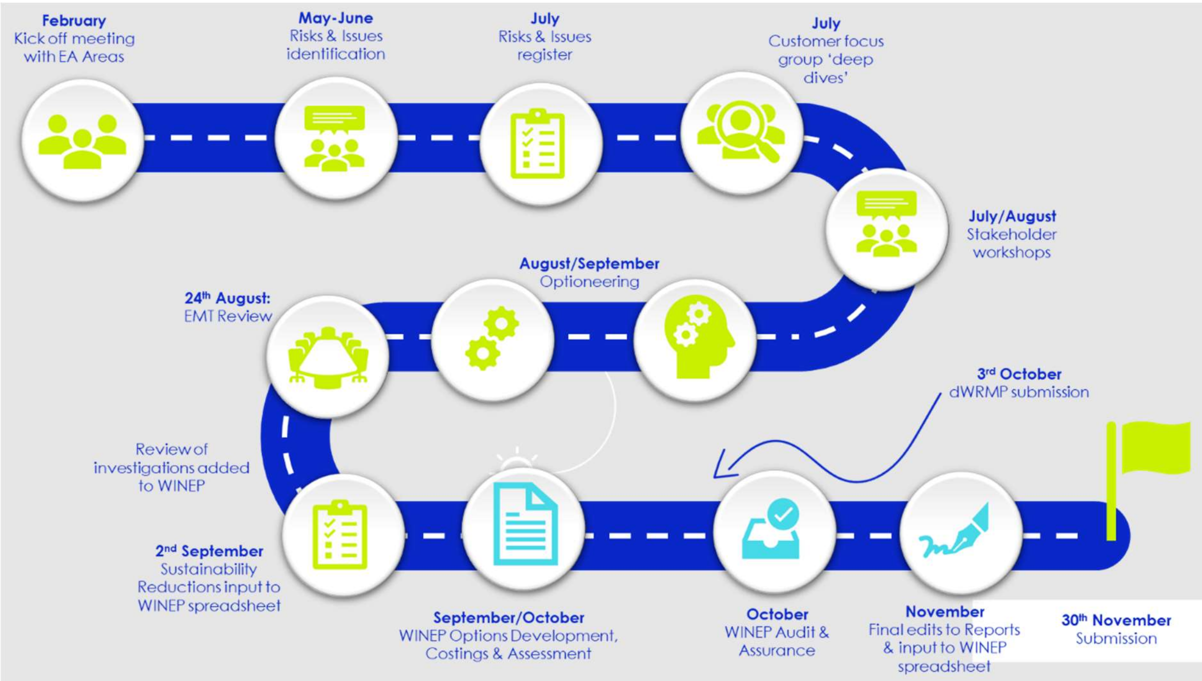

Figure 1. Schematic of our engagement process.

Co-design and Co-delivery

The current lead pipe replacement delivery team at Affinity Water actively participates in the Water UK industry steering group for lead, and across the 22+ water companies in this group we are one of four leading companies actively undertaking lead renewal trialling in AMP7. The regular meetings of the group are an opportunity to discuss planned and current approaches to tease out best practice to engagement for the issue.

Currently the four companies all have quite varied approaches to the problem and so there is not a standardised methodology for customer engagement, nor for actual means of delivery. This is to be expected when widescale resolution of the issue is in its infancy. It is also a product of local and regional variations in the existing network being rehabilitated within the activity. An issue already seen at this early stage is that company approaches have been influenced by their ability to find competent supply chains who co-understand the issue and are willing to engage on invasive projects in customer properties. This is likely to be a significant risk in the event of industry wide scale roll out.

The steering group has various working groups that are currently compiling evidence to generate databases of data and evidence, both from the UK experience and abroad (Lead has been a challenge for some time in the USA and Canada). These have looked most specifically at cost but also to a lesser extent approach and uptake levels.

Strategy Development

All of our enhancement cases have been developed as part of our integrated investment portfolio that takes the first steps of our Long Term Delivery Strategy and achieving our ambitions as laid out in AFW03 Strategic Direction Statement.

Long-term Delivery Strategy Alignment

In our Strategic Direction Statement[13] we commit to "Deliver what our customers need, ensuring affordability for all" which encompasses "Exceed[ing] customers' expectations for drinking water." We know that customers hold inherent trust in us to make the appropriate interventions to safeguard their water quality.

There is an additional commitment to "Be prepared for change and resilient to shocks and stresses" within which we commit to "Ensure a resilient supply of water for Affinity Water customers." We are delivering on this commitment in this case by providing treatment or blending where no other management of the risk is possible without detrimental effect on the resilience of our supply network in this area.

Lead Long-term Delivery Strategy

Our Lead LTDS ambition is to go beyond the regulatory requirement, supporting the Drinking Water Inspectorate's (DWI's) ambition of achieving a lead-free society.

Our lead ambition for the next 25 years will be a critical steppingstone to support the journey, whilst taking account of customer views and balancing the costs, benefits and significant deliverability challenge associated with removing all lead pipes. Our ambition is to remove all lead supply and communication pipes from customer properties in our 11 highest risk water supply zones by 2050, estimated to be approximately 76,000 pipes, 25% of the current lead asset base within our network.

Our AMP8 innovation trial will identify and test emerging technologies and approaches, collaborating with other organisations. The intent of this work will be to discover more efficient, less disruptive and/or more deliverable approaches. This approach supports our strategic long-term ambition by positioning us well to undertake a significant renewal programme commencing in AMP9, delivering at a lower overall cost over the 25-year period.

Our proactive strategy will be delivered alongside a program of reactive work replacing communication pipes at properties when random daytime sample results exceed 5 µg/l and offering to replace the supply pipe. The delivery profile for the program of work is shown in Table 2 below. Replacements where sample results exceed 10µg/l will be funded under Base, and where results are between 5 and 10µg/l they will be funded under Enhancement.

[13] AW0031_Strategic-direction-statement.pdf

Table 2 – *Lead pipe replacement delivery profile base and enhancement AMP8-12*

	AMP8	AMP9	AMP10	AMP11	AMP12
Enhancement – innovation trial	500 pipes*	-	-	-	-
Enhancement – proactive	-	7,600 pipes	15,200 pipes	22,800 pipes	30,400 pipes
Enhancement – reactive for 5-10 µg/l	500 pipes	500 pipes	500 pipes	500 pipes	500 pipes
Base – reactive above 10 µg/l	250 pipes	250 pipes	250 pipes	250 pipes	250 pipes

The investments proposed within this business case are aligned with the Core Adaptive Pathway of our LTDS and will not adversely impact any of the potential Alternate Pathways identified within the LTDS. Our core pathway to achieve our lead ambition is low regrets, as it is required across all plausible scenarios. Our strategy remains unchanged when tested against the common reference scenarios and when considering other plausible uncertainties.

Adaptive Strategy

We have carried out extensive analysis of the Core Adaptive Pathway for lead against the common reference scenarios of the LTDS. A brief justification for concluding that there is no material change to the investment plan under any of these scenarios is given below, the full reasoning can be read in the Lead strategy chapter of the LTDS.

- Climate Change

Analysis of the likely variability in water temperature due to climate change and the modelled effect this will have on plumbosolvency risk in potable water indicates that there is no material change in risk under high climate change scenario.

- Technology

We have assumed a frontier shift level of efficiency of at least 1.1% per year on the unit cost of supply and communication pipe replacement for the first 15 years of our program, which we believe to be a 'mid-point' level of improvement between the plausible extremes. We forecast the plausible extremes to be 0.6% per annum unit cost reduction across the full 25-year period for slow technology and 1.5% per annum for the first 15-years as fast technology scenario. At these extremes, NPV of the core pathway reduces 23% from core pathway for slow technology and increased 26% for fast technology. Neither of these plausible extremes materially impact the optimal phasing, however.

- Demand

Across the plausible extremes of this scenario, occupancy is expected to reduce from 2.6 in 2025 to 2.43 in 2050 under the ONS population forecast and to 2.40 under the Local Planning forecasts. In testing the sensitivity of our economic analysis, the change to the NPV of our core pathway is negligible, indicating no cause to revisit our ambition or pathway considering either extreme of this scenario.

- Abstraction Reductions

Analysis indicates that the degree of variation in water temperature within lead pipes caused by changing water sources, driven by abstraction reduction, may be up to 9°C. Under the high abstraction reduction scenario, this may apply to 30% of lead pipes in our region, and 20% under the low scenario. Water quality modelling indicates that this has a low likelihood of materially changing lead solubility, and therefore does not merit an adaptive pathway.

- Catchment Care

Catchment care is our bespoke scenario in which our initiatives to manage water quality deterioration through catchment management activities fail to deliver the forecast benefits. Our program of planned lead pipe replacement is not linked in any way to raw water quality in our source waters, and therefore does not merit an adaptive pathway.

Optioneering

We have consistently proposed best value solutions using rigorous optioneering. For more detail on our approach is provided within AFW08 Our Investment Development Process.

R&V Process

This has been conducted using the structured Risk and Value (R&V) process which is based on data and used to identify the best value solutions and/or opportunities.

The first phase of the R&V assessment is to fully determine the risks/opportunities for the service to our customers. Once a risk is fully defined, comprehensive root cause analysis is applied to determine the right source of the asset failures and the impact these have on the business. The next phase centres around solution optioneering which identifies alternative solution options, to mitigate/resolve identified risks and opportunities. The Whole Life Cost (WLC) and potential solution are evaluated using historic costs from our AMP 6 & 7 programs of work, and contractor/supply chain knowledge. The WLC is the total cost of owning and operating an asset over its lifetime. It is calculated by adding the initial capital expenditure (Capex) to the operating expenditure (Opex) over 25 years. Finally the solution options are evaluated using two important metrics: risk reduction and risk index.

Risk reduction measures the amount of risk that is removed by a proposed solution (i.e. initial risk minus percentage risk removed by solution option). Risk index measures the cost-effectiveness of a proposed solution (i.e. WLC of solution divided by residual risk). The lower the risk index the better; the solution with the lowest risk index is the best value option.

By utilising the key outputs from the R&V process the optimum solution can be identified and progressed. The stages and outputs from the R&V process are:

- Problem Definition Statement.
- Root Cause Analysis of identified risks.
- Unconstrained options – identification of any potential solution options to mitigate/resolve identified risks.
- Feasible options – selection of options to take forward based on practicality, efficacy, and affordability.
- Cost / Benefit ratios, or Risk Index, for each solution. The Risk Index is the Whole Life Cost of the solution divided by its risk reduction. The lower the risk index the better value the solution.

Selected Options

Our optioneering has looked at a range of approaches from the statutory minimum up to enhanced levels of replacement. This is both to align our approach to our long-term ambitions and also in preparation for an anticipated reduction in the lead PCV.

Do Nothing, Option 1a:

Option 1a in effect is that we continue meeting the minimum regulatory requirements of the current 10 µg/l limit, namely continue replacing or refurbishing communication pipes at properties where random daytime samples have a lead concentration when >10 µg/l is an existing baseline activity.

This option would not be sufficient to support our lead-free ambition and satisfy our customers. By taking this approach, we would be addressing the lead risk at a very small number of properties – approximately 250 per AMP, post-2030, which constitutes just 0.08% of the total number. We would be leaving the supply pipes to be removed later.

Minimal over Do Nothing, Option 1b:

Option 1b builds on the statutory minimum action covered by Option 1a by incorporating an offer to replace or refurbish supply pipes at the same time as communication pipes, where random daytime samples have a lead concentration when >10 µg/l.

The benefit of this option is that more lead will be removed from the network, leaving less for removal at a later time. However, we know that there is no safe limit for lead in drinking water and that the prescribed concentration or value (PCV) is likely to reduce to 5 µg/l in future. This approach also relies on continued phosphate dosing to reduce plumbosolvency with no preparation being made for its eventual removal from UK water treatment either before, or when phosphate supplies run out.

Replacing at 5µg/l, Options 2a/2b:

Option 2a is going further by replacing or refurbishing communication pipes at properties when random daytime sample results are 5 to 10 µg/l. Option 2b expands this further by also offering to replace or refurbish the supply pipe where the property owners consent to the work being carried out.

This approach exceeds our minimum regulatory requirements by replacing or refurbishing communication and supply pipes at properties when random daytime sample results are between 5and 10 µg/l. This is aligned with the expected change in legislation to reduce the PCV for lead at consumer taps to 5µg/l.

Since July 2021 we have taken the proactive approach of replacing communication pipes where sample results are >5 µg/l so this option continues and builds on this approach.

Replacing at 3µg/l, Options 3a/3b:

Option 3a is going further still by replacing or refurbishing communication pipes at properties when random daytime sample results are 3 to 10 µg/l. Option 3b expands this further by also offering to replace or refurbish the supply pipe where the property owners consent to the work being carried out.

This approach exceeds our minimum regulatory requirements and also goes beyond the anticipated change in legislation to reduce the PCV for lead at consumer taps to 5µg/l.

Since July 2021 we have taken the proactive approach of replacing communication pipes where sample results are >5 µg/l so this option builds on this approach and takes it even further.

Replacing at 1µg/l, Options 4a/4b:

Option 4a is the most far reaching of these options going further still by replacing or refurbishing communication pipes at properties when random daytime sample results are above the limit of detection, which is 1µg/l. Option 3b expands this further by also offering to replace or refurbish the supply pipe where the property owners consent to the work being carried out.

This approach exceeds our minimum regulatory requirements and also goes beyond the anticipated change in legislation to reduce the PCV for lead at consumer taps to 5µg/l.

Since July 2021 we have taken the proactive approach of replacing communication pipes where sample results are >5 µg/l so this option builds on this approach and takes it even further.

The benefit of this approach is that we will remove lead at every property where lead is detected, ensuring that none is left for removal at a later date.

Innovation trials, Options 5a/5b:

To facilitate our ability to remove lead more efficiently in the future we have also developed options around various innovation trials. These will be focussed on reducing unit cost and developing innovation, improving overall customer communication about lead and looking at a facilitated approach to removing lead, where we can increase the number of pipes exchanged in ways that reduce disruption and cost to customers.

Option 5a is a small-scale lead pipe replacement or refurbishment trial at properties across North London and Essex, comprising approximately 1,500 properties. This builds upon the learnings from our AMP6 and AMP7 activity and provides a test bed to look at ways to further reduce unit costs for delivery and how to tackle challenging lead renewal jobs such as shared supplies or houses converted into flats.

Option 5b is a smaller-scale lead pipe renewal trial, comprising approximately 500 properties across North London, and with similar objectives. These two approaches will align with the cross-industry approach promoted by Ofwat and coordinated through the Water UK lead steering group. The scope will therefore be dynamic and further refined through dialogue with the other water companies through the remainder of AMP7 and AMP8.

Align with Universal Metering Program, Option 6:

Option 6 involves utilising the universal metering program to identify properties where lead is present and to carry out communication pipe replacement at the same time. It is estimated that this would comprise approximately 1,000 properties per year.

The benefit of this approach is reduced overall cost, as there will be no cost associated with digging trial holes at properties to find that there is no lead present. Potentially, this approach also minimises disruption to customers as the two pieces of work could be carried out concurrently or in quick succession.

The issue with this approach is that it would not be practical to replace the supply pipe at the same time. To align with delivery of the UMP it would be necessary to limit the replacement or refurbishment to communication pipe only so that the delivery of the meter installation and pipe replacement could be delivered by a single team. The additional time required to consult with customers over options around replacement or refurbishment of supply pipes (replacement to point of entry to point of supply, for example) could not be accommodated within the combined program.

Remove Remaining Lead in Brett Community, Option 7:

Option 7 involves returning to the Brett community and continuing the proactive program of communication pipe replacement or refurbishment, alongside offering to replace supply pipes for customers at the same time.

The scope of this program would be significant, comprising approximately 25,000 properties, and would carry significant risk as we hold limited information about the location of those lead service pipes. Our experience in AMP6 and AMP7 has indicated that there is limited contractor availability and expertise across the UK currently for delivering this type of pipe replacement work.

Remove Remaining Lead in a High-Risk Zone, Option 8:

Option 8 involves selecting a single high-risk zone and attempting to proactively replace or refurbish all the communication pipes, alongside offering to replace supply pipes for customers at the same time.

The scope of this program would be significant, comprising approximately 10,000 properties, and would carry significant risk as we hold limited information about the location of lead service pipes across our company area. Our experience in AMP6 and AMP7 has indicated that there is limited contractor availability and expertise across the UK currently for delivering this type of pipe replacement work.

Align with Mains Renewals Program, Option 9:

Option 9 makes use of the company existing Mains Renewals programme to opportunistically renew lead communications pipes at lower unit costs and with reduced customer disruption. The approach would involve ad hoc replacement or refurbishment of lead communication pipes when identified through existing mains renewals projects. This approach will help to increase overall company renewal rates and result in little additional disruption for customers alongside the general activity already underway during a mains renewal.

The issue with this approach is that it would not be practical to replace the supply pipe at the same time. To align with delivery of the mains renewals program it would be necessary to limit the replacement or refurbishment to communication pipe only so that the delivery of the mains renewal and pipe replacement could be delivered by a single team. The additional time required to consult with customers over options around replacement or refurbishment of supply pipes (replacement to point of entry to point of supply, for example) could not be accommodated within the combined program.

Option Assessment Approach

Economic Assessment

An R&V was conducted to review all of the options identified in this business case, to identify the risks posed to consumers and the potential approaches. Each option was costed using data from delivery programs in previous AMPs.

A Net Present Value (NPV) cost benefit analysis was conducted using an NPV period of 30 years, with a depreciation period of 45 years. Risk mitigation factors were applied to each option's NPV assessment directly, based on the most significant service impacts to the business that were identified from the relevant R&V.

Cost Estimation

Cost forecasting for pipe renewal activities is based on AMP6 or AMP7 actual delivery data (set to 2022/23 price base) and we have a high degree of confidence.

Activity in North London Boroughs was last conducted in AMP6. In the interim period it has been assumed that no new charges have been introduced over those already factored into the modelling.

Innovation projects are difficult to cost due to the inherent unknowns and variables involved. Sound engineering judgement based on previous experience has been used in some cases based on similar areas of experience in other business areas.

Benefit Estimation

The health benefit research carried out by DWI has shown that there is a marginal health benefit to the removal of all lead pipework at a per property level. The benefit of pipe renewal (whether communication pipe only, or communication and supply pipe) is very closely aligned with the current unit costs for delivery of this approach. For most properties this means that there is a benefit to removing the pipework, but it is not a strong economic driver for doing so. For selected properties with vulnerable residents, or those with a higher number of children present, then the economic driver of intervention becomes stronger and may make pipe renewal economically viable as a standalone driver for intervention.

For most properties where there are economic benefits, but not a positive economic driver for doing so, then other factors may become influential over time to justify widescale roll out of activity. For example, additional benefits may help to make the economic case, through reduced supply pipe leakage. It is also the case that any reductions in the unit cost of lead pipe renewals would make marginally viable renewal activity have a positive cost benefit through relatively small changes in unit cost.

Efficiency

The costs derived for the options are based on the AMP6 and AMP7 costs incurred by the business in delivering components of work that brought together make up the activities proposed in the options. For the pipe renewal options the disparate nature of the sites where activity is required limits any ability to drive additional efficiencies.

However, pipe renewals on an individual basis can be delivered under different permit conditions and this can facilitate works with lower on costs due to the shorter duration. This may be seen through different traffic management conditions, not needing to suspend bus stops, or parking bays and other potential efficiencies such as collaborative working.

A year-on-year efficiency of 1.1% has been applied to unit costs to take into account efficiency over time and incremental technology developments.

Assumptions Made

The main assumptions made are:

- That aspirations stated by the Regulator do ultimately translate into reductions in permissible lead concentration.

- That the increases in labour that would be required to deliver these projects are also skilled enough to be able to deliver the activity without significant impacts on safety, productivity and customer experience.
- That no additional unforeseen significant delivery costs are incurred during works that were not present when the cost model activity was undertaken.
- An assumption that future innovations will become apparent over time that support delivery with lower unit cost rates and allow options to consider cessation of orthophosphate dosing.
- That the business continues Mains Renewal activity at sufficient enough scale that lead renewals during these works remains a viable option, as a potential means of delivery.

Uncertainties and Sensitivity Analysis

A number of uncertainties exist in terms of future scope for lead activities, potential approach and access to undertake delivery. The main uncertainties known at this time are as follows.

While we will offer all customers the opportunity to remove their supply pipes, we anticipate that take-up of this offer may be lower than 100% based on the results of our AMP7 trials. This was discussed in detail in the section on 'Research, Pilots, and Technology Development.'

There is a financial value attributed to each property where lead is removed, based on the health benefits to occupants. This number is fixed per property, so if the unit cost to deliver the removal can be reduced, then the cost-benefit ratio will improve.

We carried out sensitivity testing on the economics of the program to assess whether plausible variability in any of our core assumptions would affect the economic balance of the program. We found that neither the plausible extremes of technology development leading to unit cost reduction nor the extremes of plausible delivery profiles changed the best economic approach from our core pathway.

There is significant uncertainty over when regulatory changes will be brought about to further manage the risk posed by lead pipes. This may be in the form of reducing prescribed concentration values acceptable within drinking water, or in providing water companies powers to change pipe materials on the customers' side. This uncertainty may materially change the level of need for investment and in the cost or effectiveness of investments. Neither case negates the benefit of our 2025-30 investment, which remains 'no regrets.'

Carbon assessment

To facilitate an effective and efficient process to look at the implications of the PR24 Business Cases on carbon (operational and embedded) all Business cases were screened with relevant Business case leads to ascertain where there was potential for material impact on Carbon, Biodiversity or Natural Capital. Once the potential for an impact was identified the significance associated with that impact was explored with relevant specialists and business case leads.

Figure 2. High Level Schematic of the Carbon Assessment Process

Surgery sessions were held with business case leads to set out considerations for each of the three assessment areas. Criteria to assess significance of carbon impact included:

- A material increase or decrease in operational CO2 emissions and/or
- An impact on capital carbon, e.g. identification of requirement for a physical build or change in capital maintenance resource use

Both the embedded carbon (resulting from construction activities) and operational carbon (resulting from energy and chemical use) were assessed using Affinity Water's bespoke asset carbon estimation tool which includes over 400 different carbon models covering the types of below ground and above ground assets we typically construct and operate. The outputs of the carbon assessment (as tCO2e) can be seen below.

Option	Mitigation Solution option	Total properties in AMP8	Total metres	Total Carbon (t CO2e)
1a	Continue replacing or refurbishing communication pipes at properties where random daytime samples have a lead concentration when >10 µg/l.	250	1535.8	49.1875
1b	Continue replacing or refurbishing communication pipes at properties where random daytime samples have a lead concentration when >10 µg/l and replace or refurbish the supply pipe where the property owners' consent to the work being carried out.	250	5235.77	479.31
2a	Replacing or refurbishing communication pipes (free of charge) where random daytime samples have a lead concentration >5 and 10 µg/l	500	3071.55	98.375
2b	**Replacing or refurbishing communication pipes (free of charge) where random daytime samples have a lead concentration >5 and 10 µg/l and offering to replace or refurbish the supply where the property owners' consent to the work being carried out.**	**500**	**10471.55**	**958.63**

Option	Mitigation Solution option	Total properties in AMP8	Total metres	Total Carbon (t CO2e)
3a	Replacing or refurbishing communication pipes (free of charge) where random daytime samples have a lead concentration >3 and 10 µg/l	1,500	9214.64	295.125
3b	Replacing or refurbishing communication pipes where random daytime samples have a lead concentration > 3 and 10 µg/l and offering to replace or refurbish the supply where the property owners' consent to the work being carried out.	1,500	31414.64	2875.88
4a	Replacing or refurbishing communication pipes (free of charge) where random daytime samples have a lead concentration >1 and 10 µg/l	3,750	23036.59	737.813
4b	Replacing or refurbishing communication pipes where random daytime samples have a lead concentration >1 and 10 µg/l and offering to replace or refurbish the supply where the property owners' consent to the work being carried out.	3,750	78536.59	7,189.688
5a	Small scale innovation trial at 1,500 properties across Essex and North London, aligned to wider Ofwat approach, seeking to drive unit cost reductions and targeted approach on 'difficult' properties. Full pipe replacement.	1,500	31414.64	2,875.875
5b	**Small scale innovation trial at 500 North London properties, aligned to wider Ofwat approach, seeking to drive unit cost reductions and targeted approach on 'difficult' properties. Full pipe replacement.**	**500**	**10471.5**	**958.625**
6	Align with metering programme to track where lead pipes are to be renewed, replacing communication pipes only at those properties.	5,000	30715.46	983.750
7	Replace all remaining lead pipes in the Brett community, supply and communication pipes, to enable cessation of orthophosphoric acid dosing.	25,000	523577.2 9	47,931,250
8	Replace all lead pipes in a single high-risk zone, supply and communication pipes.	10,000	209430.9 2	19,172.500
9	Facilitated renewal of lead communication pipes during Mains Renewal activity (Max of 170 properties per year)	850	5221.63	167,238

Third Party Assurance and Audit Trail

Cost data was provided through supplier quotes as well as Affinity Water's own costs from the AMP6 and AMP7 lead replacement programs.

An R&V workshop was held to review the risks and potential solutions using up to date data.

Cost models are based on data from other businesses in the water industry which further strengthens the reliability of the data. The carbon model used is also based on ongoing information sharing with Motts MacDonald.

Option Assessment

Commentary on the Economic Assessment

Option	Mitigation Solution option	Total properties in AMP8	Total AMP8 Capex (£)
1a	Continue replacing or refurbishing communication pipes at properties where random daytime samples have a lead concentration when >10 µg/l.	250	£0.56m (Base)
1b	Continue replacing or refurbishing communication pipes at properties where random daytime samples have a lead concentration when >10 µg/l and replace or refurbish the supply pipe where the property owners consent to the work being carried out.	250	£1.00m (Base)
2a	Replacing or refurbishing communication pipes where random daytime samples have a lead concentration between 5 and 10 µg/l.	500	£1.12m
2b	**Replacing or refurbishing communication pipes where random daytime samples have a lead concentration between 5 and 10 µg/l and offering to replace or refurbish the supply where the property owners consent to the work being carried out.**	**500**	**£2.00m**
3a	Replacing or refurbishing communication pipes where random daytime samples have a lead concentration > 3 µg/l.	1,500	£3.37m
3b	Replacing or refurbishing communication pipes where random daytime samples have a lead concentration > 3 µg/l and replace or refurbish the supply where the property owners consent to the work being carried out.	1,500	£6.00m
4a	Replacing or refurbishing communication pipes where random daytime samples have a lead concentration > 1 µg/l (above limit of detection).	3,750	£8.41m
4b	Replacing or refurbishing communication pipes where random daytime samples have a lead concentration > 1 µg/l (above limit of detection) and replace or refurbish the supply where the property owners consent to the work being carried out.	3,750	£15.00m
5a	Small scale innovation trial at 1,500 properties across Essex and North London, aligned to wider Ofwat approach, seeking to drive unit cost reductions and targeted approach on 'difficult' properties. Full pipe replacement.	1,500	£6.00m
5b	**Small scale innovation trial at 500 North London properties, aligned to wider Ofwat approach, seeking to drive unit cost reductions and targeted approach on 'difficult' properties. Full pipe replacement.**	**500**	**£2.00m**
6	Align with metering programme to track where lead pipes are to be renewed, replacing communication pipes only at those properties.	5,000	£11.25m
7	Replace all remaining lead pipes in the Brett community, supply and communication pipes, to enable cessation of orthophosphoric acid dosing.	25,000	£99.99m
8	Replace all lead pipes in a single high-risk zone, supply and communication pipes.	10,000	£40.00m
9	Facilitated renewal of lead communication pipes during Mains Renewal activity; at 0.5% rate aligned with mains renewal program	1,560	£11.70m

The basis of the costs in terms of actual service pipe renewals all come from previously delivered activity and therefore costs for all options are data driven predominantly based on recent experience. The costs of each option are given in the summary table above.

Option 9 is based on renewing communication pipes only and it is possible that works completed under mains renewals (MR) could potentially have a lower unit rate (as MR activity will already be exposing the services ferrule). As such, we have applied a 35% cost saving on the unit cost for communication pipe renewals for this option.

There is no difference in unit cost between the options, it is just the scope or ambition of the program that varies. As such there is a very linear relationship between the number of pipe replacement or refurbishments delivered and the benefit delivered to customers. Our net present value analysis indicates that the cost/benefit ratio for the options vary between 1.09 and 1.22 indicating that they are all slightly cost beneficial but that cost is not a primary driver for this program.

Preferred, Best Value, Option

The preferred best value option is to combine Options 2b and 5b. This would mean replacing or refurbishing communication pipes where random daytime samples have a lead concentration >5 and 10 µg/l and offering to replace or refurbish the supply where the property owners' consent to the work being carried out and undertaking the small-scale lead innovation trial to grow our learning and knowledge.

When these two options are undertaken alongside the base activity, Option 1b, of renewing communication and supply pipes at >10 µg/l sample failures then adoption of this approach is best value, is affordable for customers and positions us well for the large program to commence in AMP9.

This approach will also have small scale leakage benefits against supply pipe leaks and is at a delivery scale that is well within existing run rates familiar to supply chain. It demonstrably exceeds the regulatory minimum and aligns us to likely future changes in permissible lead level reductions so ensures we are adapted to a new limit being introduced without substantial additional spend that is borne by customers in the short term and as such could be considered lowest regret.

This activity combined with the small-scale innovation trial (Option 5b) allows the business to also continue aligning with Ofwat and the wider industry's stated ambition to fund trials and collaborate on designing those trials at overall least cost to the customer. The trial can continue building upon the learnings made by Affinity Water through AMPs6 and 7 and there is enough scope for areas of learning (new innovations, pipe detection methods, shared supply properties, willingness to pay / tenanted properties etc) for the trial to be standalone.

Equally, by continuing to collaborate with the wider industry on AMP8 trial design, then this may allow us access to the wider trial learnings in AMP8 and therefore gain more in learnt benefits from all collaborative trials than the innovation benefit that would be yielded from our standalone trial learnings.

Least Cost Option

Least cost option is 1a because this level of baseline activity is compliant with the existing regulatory standard. This would not be sufficient to support our lead-free ambition and satisfy our customers. By taking this approach, we would be leaving the supply pipes to be removed later. It should be noted that this approach does not position us well for the significant lead removal and replacement program as per our long-term delivery strategy across AMPs 9 to 12. This approach would not capitalise on the learning gained from our AMP6 and AMP7 lead activities.

Alternative Option 1

There are no identified, acceptable alternate options due to scale and deliverability issues, or the risk of leaving too much lead in the network as a result of limiting the program to communication pipe replacement only

Meeting Affinity Water's Outcomes

The requirement for this investment is to meet the commitments set out in our Strategic Direction Statement to "Deliver what our customers need, ensuring affordability for all," which encompasses "Exceed[ing] customers' expectations for drinking water," and to "Be prepared for change and resilient to shocks and stresses".

There will be no short to medium term meaningful effect on the Compliance Risk Index (CRI) score as a result of lead replacement programme, as the contribution to CRI score from each compliance failure is negligible with our current orthophosphoric dosing strategy, and we can usually demonstrate that the risk was limited to a single property.

The enhancement investment proposed for AMP8 will result in a critical steppingstone to support our journey for enabling a 'lead-free society', whilst taking account of customer views and balancing the costs, benefits and significant deliverability challenge associated with removing all lead pipes.

Justification of the Preferred Option

The preferred approach is **Option 2b** combined with **Option 5b** together for £4.00m investment.

When these two options are undertaken alongside the base activity of renewing communication and supply pipes at 10 µg/l sample failures then adoption of this preferred option is best value and as such makes a strong case for keeping the company compliant with the current 10µg/l standard, while making sufficient preparations for a potential 5 µg/l regulatory standard in the future.

This approach will also have small scale leakage benefits against supply pipe leaks and is at a delivery scale that is well within existing run rates familiar to supply chain.

This activity combined with the small-scale innovation trial (Option 5b) allows the business to also continue aligning with the wider industry's stated ambition to fund trials and collaborate on designing those trials at overall least cost to the customer. This puts us in a stronger position than the "do nothing" option in terms of aligning with the Regulators desire for water companies to show ambition with our enhancement cases, but at lowest realistic cost to the business of doing so.

By having a trial within our enhancement case, then this gives us justification to continue collaborating with the wider industry on AMP8 trial design, and justification to share in the wider trial learnings in AMP8. This means we can gain more in learnt benefits from all collaborative trials than the innovation benefit that would be yielded from our standalone trial learnings alone.

This approach also allows us to further develop and drive our understanding of how to deliver a coherent response to lead, driving efficiency and cost reductions into our existing methodology (communication and supply pipe renewals) and determining if this is the optimum approach how to deliver it at greater scale and with a well-developed and skilled workforce.

The approach also recognises that a widescale roll out of the current methodology without refinement may actually not be the optimal delivery method, therefore provides a space to understand what other alternative solutions and innovations may be available to us in the longer term.

Our long-term delivery strategy builds upon this and aims to increase investment levels as and when the time is right to do so. Overall, this approach provides a coherent approach to the challenge of lead in the short-term that aligns with our customers' and stakeholders' views. It utilises an adaptive pathway approach with low regrets, whilst being ambitious over the longer-term.

Delivery Considerations

Related Projects

None

Lessons Learnt

In AMP6 the company undertook communications pipe replacement in Watford and Barnet, London. This work identified appropriate working methodologies for street-by-street activity in busy urban areas and methods of working to renew ferrules in the water main plus workarounds for various challenges. It also identified streets and areas where lead renewal could not be completed. The programme was also used as an innovation test bed, trialling activities such as pipe lining, and use of Arctic Driver, a tool for replacing ferrules under pressure via overclamping.

In AMP7, we trialled the renewal of the full-service pipe from ferrule to customer Internal Stop Valve (ISV). This activity in our East area initially focussed on developing the proof of concept for the work and the outputs from this activity have been data around costs and uptake rates. We have also determined sound working methodologies for delivery and a basic understanding of delivery costs in simple working areas.

The current company base response of renewing lead communication pipes at 5 μg/l sample failures has given a basic structure to how future works of this nature can be completed, which would need to be combined with learnings from the AMP7 lead trials activity if a new supplier was required to support the 5 μg/l communication and supply pipe renewals.

Delivery Risk Management

Access to target streets within the high-risk zones, only at the permission of the relevant Highways Authority through the street works permitting scheme and in queue of other utilities looking to conduct similar activity in the same areas. The benefit of the proposed approach is pipe renewals would be individual and therefore this activity could be completed under minor, or standard works permits. these are generally much more amenable to highways authorities than major works notices facilitating delivery at lower overall cost.

Take up by customers for any activity relating to the supply pipe. We have no enforcement powers for supply pipe activities so all works are at express permission of the customer.

Supply chain ability to provide delivery capability and competence to support the planned activities to the timescales demanded, as the activity would be applicable over whole company area.

Substantially increased costs prior to delivery through inflation, materials price rises and supply chain increased costs.

Further detail regarding how we have ensured the deliverability of our full investment portfolio is provided within AFW 32 Deliverability of our Plans

Monitoring and Reporting of Benefits

The delivery of this lead replacement program will be tracked in line with capital delivery milestones and will be monitored as a priority to ensure it achieves the deadlines set in the PCD. A dedicated Treatment Board forms part of the governance monitoring, where any issues with time, cost, or quality can be escalated and resolved in a timely manner.

We will continue to monitor the concentration of lead at consumer taps in our supply network through our random daytime sampling program, to verify our baseline assumptions about prevalence and extent of lead in our supply network.

We will take repeat samples at properties where lead pipe has been refurbished or replaced, whether to the boundary stop tap, the point of entry to the property or to the kitchen tap, to assess the effectiveness of the work carried out on reducing the lead concentration at the consumer's tap.