PR24

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A3-21 ASSET HEALTH INVESTMENT

NES35

1. EXECUTIVE SUMMARY

WE ARE CONCERNED THAT THERE IS INSUFFICIENT INVESTMENT IN ASSET MAINTENANCE AND REPLACEMENT ACROSS THE SECTOR

The water sector delivers critical essential services to customers through a large and complex asset base that needs to be maintained effectively. If the assets we operate are not maintained effectively then those essential services are put at risk. We are concerned that the sector in England and Wales may not be investing sufficiently in the maintenance and replacement of its assets. This is because:

- Our historical levels of capital maintenance expenditure are not close to the levels implied by the lives of the asset base we manage. In 2021-22 we completed work with the Water Industry Commission for Scotland (WICS) and Scottish Water examining the current replacement rates of different asset groups against the expected replacement rates based on the economic lives of those assets. This work suggested that we are currently maintaining and replacing assets at a materially lower rate that is implied by the lives of those assets.
- Over the last five price control periods by 2025 the sector will on average have has spent its total expenditure allowances in full by 2025 and capital maintenance allowances have been spent in full for those price control periods when such allowances were separately defined (PR99-PR09). This is also true for Northumbrian Water, in aggregate since 2000 we have overspent our capital maintenance allowances after cost sharing.
- We see a steady growth in levels of reactive maintenance expenditure over time as the assets deteriorate and lower investment levels in areas of the asset base which are less critical to service delivery to customers or where asset lives are longer.
- We are overspending relative to our allowances in the current period in part to undertake additional mains renewal and other asset health investments as we see this activity as critical for the long-term resilience of our business.
- Further analysis carried out for Water UK has confirmed many of the same concerns[1] and highlights the low renewal rates of some assets compared to international comparators and the declining depreciation rates across the sector.

There is also compelling evidence that the past may not be a good guide to the future and that to achieve net zero and meet stretching future service performance in areas like leakage we will likely need to invest more in asset renewals. Indeed, we identify in a separate case that we will need to replace more mains in Suffolk as a result of the challenges posed by achieving further leakage reductions in that area given its relatively strong leakage position.

This issue was also considered by the CMA during the PR19 appeals as well as WICS in the setting of price controls for Scottish Water in 2021 (SRC21).

- In the PR19 appeals whilst the CMA did not find evidence of an 'investment trough' in the historical expenditures that Ofwat used to derive base capital maintenance allowances and made no additional allowances in its determinations.

[1] Economic Insight, 2022, Options for a sustainable approach to asset maintenance and replacement, LINK

However, it did recognise the same concerns we highlight here that an approach to cost assessment which is backward looking and assumes a stable profile for capital maintenance is unlikely to be appropriate and the CMA encouraged Ofwat to examine its methodology more broadly. This issue was also explored in a report by Harry Bush and John Earwaker[2].

- In SR21 WICS concluded that the appropriate approach to protect the long-term interests of customers was to enable an 80%+ uplift to the capital maintenance allowances of Scottish Water to better address these issues[3]. This was based on substantial work with Scottish Water to understand the efficient level of long-term capital maintenance for their different asset types, a particularly difficult issue to resolve given the range of assets and the very long lives of some of them.

WE RECOGNISE THAT WIDER CHANGES ARE NEEDED IN THE FUTURE TO THE REGULATORY FRAMEWORK AND ARE COMMITTED TO SUPPORTING THOSE CHANGES.

This is a complex problem and there is a clear need to understand the issues and challenges better and consistently at a sector level through a common framework for assessing and independently verifying levels of asset health. Until this framework is in place and information is available consistently and robustly, it will be difficult to reveal the extent of the problem and to delineate between underfunding and inefficiency or deferment. This requires a long-term approach with substantial change across multiple price controls.

We note that the National Infrastructure Commission has also written to Ofwat and raised similar concerns about the lack of a comprehensive and consistent set of information about asset condition across the sector[4]. Our **report to Ofwat's Future Ideas Lab** highlighted wider reforms that would be needed which are very consistent with the concerns and sentiment expressed by the NIC in their open letter. We have welcomed Ofwat's work constructing the Asset Management Maturity Assessment (AMMA) and have been supporting that work we include a recent assessment of our performance against that framework which demonstrates that we sit in the top cohort of companies for asset management[5]. We are also working on the development of better risk-based and forward-looking measures of asset health that could replace the current limited and lagging metrics that form the basis of the asset health Performance Commitments.

We remain committed to resolving these issues with Ofwat in the future and our **Long Term Strategy** (LTDS) describes how we hope to make progress towards some of these changes for PR29 and beyond.

OUR ASSET HEALTH ENHANCEMENT CASE FOCUSES ON 'NO REGRET' ACTIVITIES FOR THE 2025-30 PERIOD.

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[2] Bush Earwaker, 2019, PROVIDING APPROPRIATE REGULATORY FUNDING FOR CAPITAL MAINTENANCE ACTIVITY: ENSURING CAPITAL SUSTAINABILITY AND SERVICE RESILIENCE **LINK**

[3] WICS, 2019, Decision paper Strategic Review of Charges 2021-2027: Asset replacement, **LINK**

[4] **20230612-Ltr-from-David-Black-to-James-Heath_NIC.pdf (ofwat.gov.uk)**

[5] ARUP, August 2023, Northumbrian Water, Asset Management Maturity Assessment

However, given the challenges we don't think we can wait for that new framework to be in place. We initially examined our asset base to identify those assets which are most critical to the delivery of service to our customers, where we had the least information about their health, where we had the greatest concerns about ongoing funding and where the scope for deferment of investment was lowest. This work identified the **civil structures on our treatment works** as key areas of concern. We completed substantial work and independent investigations of those assets to assess their condition and to be able to forecast future deterioration of those assets and based on that work we propose an enhancement case for additional investment of £17.8m in water and £94.4m in wastewater to repair and replace those assets that are in the worst condition in the 2025-30 period. This is after we have taken into account of the funding that will already be available in the base cost allowances so customers do not pay twice through a project-level review of our historical expenditure and analysis using our Fixed Asset Register (FAR).

FIGURE 1: OVERVIEW OF OUR CIVIL ASSETS PROPOSAL FOR THE PR24 BUSINESS PLAN

Expenditure	Water	Wastewater
Analysis of our fixed assets register (FAR), 2015-2021	£39.9m	£75.3m
FAR implied implicit allowance	£28.5m	£53.8m
Project level review	£11.4m	£17.9m
Resulting implicit allowance for AMP8	**£8.1m**	**£12.8m**
Our proposed proactive maintenance programme	£24.2m	£102.6m
Ongoing minor maintenance	£1.7m	£4.6m
TOTAL 2025-30 spend	**£25.9m**	**£107.2m**
Additional enhancement allowance	**£17.8m**	**£94.4m**

We have undertaken analysis of the future cost of undertaking this work should it be deferred which shows that customers will need to pay substantially more in future AMPs. We have also undertaken consequence analysis which similarly confirms that should these assets fail the impacts could be very severe further justifying the costs of repair and replacement associated with this investment.

In its final methodology Ofwat stated that it would be open to cases for more **water mains renewal** investment as well. We were pleased to see Ofwat recognise the problem with capital maintenances allowances, but we were surprised that this focused on water mains - which are just one group of assets that we manage and operate. We are also concerned about levels of mains renewal – for us, and across the sector as a whole - and so we also explored the need for further 'no regret' investments in this area. Over the past five years, consistent with the period covered by Ofwat's cost assessment model efficiency calculations, the sector has replaced around 0.17% of its mains. The long-term efficient and economic rate of mains renewal is not known, but the current replacement rate is very unlikely to be sufficient given that these assets are generally expected to have a life of between 63 and 125 years from the various sources we consider. At the current rate across the industry, we would be expecting these assets to last for over 500 years. This enhancement case therefore includes investment to:

- Replace 0.17% of water mains per year from our existing base allowances in the 2025-30 period. This is consistent with the levels that the sector has delivered over the last five years (the same period Ofwat examines in setting the efficient base cost modelled allowances). We note that this level of mains renewal appears higher than the levels achieved by the benchmark companies Ofwat may use to set base allowances.
- We have separately set out that in order to reduce leakage further in our Essex and Suffolk operating area as part of our Water Resource Management Plan (WRMP) we would need to undertake additional mains renewal amounting to a further 0.03% per year, this would be added to the 0.17% but involves replacing different mains focussed on reducing leakage. This is addressed in our demand management enhancement case (NES15).
- Replace an additional 0.2% of mains per year on top of these levels at an efficient unit rate of £273.47 per metre.

We examined a range of other options in the case looking at higher and lower rates of mains renewal and used our network analysis tools to identify the potential impact these options had on bursts and interruptions. We commit to the delivery of those benefits for customers from our proposed, although most will be seen in future price control periods.

At the 0.4% overall renewal level and reflecting the additional investment that we are making in this AMP period, in aggregate our analysis suggests we can maintain a relatively stable bursts rate which ensures that any further deterioration is arrested or delayed and reflects the feedback we received from customers which encouraged us to strike a balance between investing to ensure we are not storing up issues for the future but recognising the current cost of living crisis. Moreover, even though the long-run economic level of mains renewal is unknown 0.4% is still below the range we identified in the evidence we reviewed and allows time for the further work we have identified to be completed and that economic level to be better defined. During the 2025-30 period we will support further work, which could be carried out with Ofwat and other companies, to identify the long-term efficient level of mains renewal or indeed to examine the efficient and economic level of capital maintenance more broadly. This could then be used to inform the approach taken in PR29.

FIGURE 2: OVERVIEW OF OUR MAINS RENEWAL PROPOSALS FOR AMP 8

	Unit cost per meter (£)	Km of mains to be replaced in AMP 8	Renewal rate	Total cost £m
1. Base 0.17% mains renewal p.a.	273.47	231.12	0.17%	63.20
2. Leakage Case (NES 15)	296.72	42.7	0.03%	12.67
3. Enhancement case for an additional 0.20% mains renewal p.a.	273.47	271.91	0.20%	74.36

Source: NWL analysis

	2025/26	2026/27	2027/28	2028/29	2029/30	AMP8
Forecast length of potable mains (km)	26925	27080	27163	27323	27463	
Implicit renewal rate (%)	0.17	0.17	0.17	0.17	0.17	
Implicit length of mains renewed (km)	45.77	46.04	46.18	46.45	46.69	**231.12**
Implicit allowance (£m)	12.52	12.59	12.63	12.70	12.77	**63.20**
Forecast renewal rate (%)	0.37	0.37	0.37	0.37	0.37	**-**
Forecast length of mains renewed (km)	99.62	100.20	100.50	101.10	101.61	**503.03**
Gross allowance (£m)	27.24	27.40	27.48	27.65	27.79	**137.56**
Net Allowance	14.73	14.81	14.86	14.94	15.02	**74.36**

We have benchmarked both sets of costs independently to ensure that they are efficient.

CUSTOMERS RECOGNISE AND SUPPORT INVESTMENT IN MAINTAINING THE HEALTH OF THE ASSET BASE AND ACCEPTED INVESTMENT IN THIS AREA IN OUR PR24 BUSINESS PLAN ALONGSIDE OTHER BILL PRESSURES.

We have engaged extensively with our customers and the Water Forum on these complex and long-term issues, both in preparing our PR24 business plan and more broadly. Most customers prioritise other service improvements over asset health, placing asset health improvement as a 'medium' or 'low' priority area (prioritisation of common PCs, NES44).

When discussed in a long-term context customers understand the importance of asset health and support our long-term ambitions for improvement. Our customers support at least this level of investment in asset health – and many would support higher investment still.

We tested our civil structures proposals with customers twice, as part of our pre-acceptability research and as part of the qualitative Affordability and Acceptability testing (NES49). We tested our mains renewal proposals as part of qualitative acceptability testing. We discuss customer support in more detail in 3.6.

WE PROPOSE TO USE PRICE CONTROL DELIVERABLES WITH COMMITMENTS TO PROTECT CUSTOMERS.

We propose price control deliverables which will return funds to customers for partial or non-delivery of this activity, for both civil structures and mains renewal. This will follow the efficient unit rates and volumes set out in the enhancement case. Our proposed PCDs will further recognise our stated concern that there is simply insufficient funding across the sector for capital maintenance and replacement of assets. In that spirit we will further commit that:

- We will retain a minimum AMMA rating across the period of 'competent' and also retain our ISO 55001 accreditation to ensure confidence that we are continuing to manage our assets effectively;
- We will spend all our capital maintenance allowance in the 2025-30 period otherwise that will be used to fund these investments not the additional allowances we are seeking; and

- If we are able to achieve the lengths of mains renewal or civil structures replacements as set out in this enhancement case for less than the allowances stated, then we will reinvest any available money in further capital maintenance activities but overspending will be subject to cost sharing.

We firmly believe in the concept of incentive-based regulation and that there should be strong incentives for efficiency within the regulatory framework. By committing to reinvest and share benefits with customers we recognise that we are reducing those incentives but we hope this allows Ofwat the freedom to review our case with an open mind to the challenges we highlight so that we can work together to makes changes for the long term benefit of customers.

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2. INTRODUCTION

This enhancement case presents the evidence for the need for additional funding to deliver the investment required to maintain the health of the asset base we manage, above the 'base' cost allowances we expect from Ofwat's cost assessment methods for PR24. We highlighted the need for further work in this area in our paper for the Ofwat Future Ideas Lab in 2022, and our case focuses on 'no regrets' investments in the areas of **civil asset replacement** and **water mains renewal**.

2.1. STRUCTURE

The case is structured to follow Ofwat's PR24 methodology requirements for enhancement cases while also taking account of the tests for cost adjustment claims described in Ofwat's PR24 final methodology. The case is not seeking to suggest that we are different to other companies in the water industry, as we expect the issues discussed in this case to be similar to those experienced by other companies across the sector. So, we consider that this case more appropriately meets Ofwat's 'enhancement' case tests.

Ofwat allows companies to submit cost adjustment claims for "factors outside of company control that cause material differences in costs between companies and/or over time and are not captured in our benchmarking analysis". In practice, our case for asset health investment shares more features with enhancement claims – that is: there are no unique circumstances or drivers for Northumbrian Water; and there are more relevant questions under the "need" section for enhancement criteria that should be asked in considering this case (particularly on customer evidence and long-term plans). The business plan tables for cost adjustment claims focus only on claims where companies are different from others in the sector, and do not seem sufficient to explain these investments and their benefits.

There is no scope for these investments to be symmetric adjustments in base cost models, and we describe actual proposed investments and their costs and benefits, rather than seeking a general uplift based on cost drivers alone. These investments have not been considered already in developing base cost models.

Our email response of 4 July explained that we had assumed that only symmetrical cases should be submitted early and so had not submitted any cost adjustment claims. However, recognising that Ofwat was keen to see these cases as soon as possible, we brought forward our timelines and so have provided our case before we submit our full business plan.

Section 3	**Need for investment**	This section seeks to: • Summarise why maintaining good asset health is important for customers. • Provide evidence that the current levels of capital maintenance and asset replacement are unlikely to be economic and efficient across the sector, and more will be needed in the future. • Summarise the views of customers on these issues based on the research we have undertaken. • Explain why our case targets 'no regrets' investment in AMP 8
Section 4	**Targeting civil structures and mains renewal**	This section provides an analysis of our asset base and explains why we have targeted our case on civil structures and mains renewal. It also provides information on the nature, condition, age and material type of these various asset types and discusses evidence on the long-term renewal rate of our mains.
Section 5	**Comparison to base allowances**	This section provides evidence that, while the maintenance of these assets is entirely within management control, the investment required is not fully accounted for in modelled allowances and is material. This analysis is provided separately for civil structures and mains renewal.
Section 6	**Best option for customers**	This section explains: • How we have developed our proposals for investment and identified our preferred options for investment including the costs and benefits of the preferred solutions for customers • The evidence we have of customer support for these proposals. • Why the proposals are not suitable for DPC in either instance; nor are we able to secure third party funding.
Section 7	**Cost efficiency**	This section provides evidence that the cost estimates we propose are efficient including benchmarking of those costs wherever possible.
Section 8	**Customer protection**	This section includes our proposals for price control deliverables to protect customers if the investment is not delivered, delayed or reduced in scope.
Sections 9-13	**Annexes**	Five annexes are provided including: A. A method statement explaining how our Fixed Asset Register (FAR) analysis was undertaken. B. A list of detailed case studies on our civil asset structures C. A list of the civil structures categorised into value bands which is necessary for the PCD proposed D. A summary table of all the civil structures at condition grade 4 or 5 from the independent survey evidence E. A description of how we have undertaken our consequence analysis of the potential impact of civil asset failure

3. NEED FOR INVESTMENT

Like other water companies, we have a critical need to invest in the maintenance and replacement of our asset base. If assets become damaged or unavailable, then the corresponding impacts on customers can be severe. Section 3.1 highlights this and section 3.2 provides an interesting case study from New Zealand.

We are concerned that the sector is not investing sufficiently in the maintenance and replacement of its asset base (see section 3.2). This concern is reflected in our most recent risk and compliance statement and our corporate risk register.

- Our historical levels of asset replacement are below (and not close to) the levels that would be needed to meet the levels implied by the lives of the asset base we manage.
- By 2025, the sector will have spent its allowed totex in full over the last 25 years (on average), including and especially its capital maintenance allowances. We have overspent against our capital maintenance allowances over the last five price control periods, when cost sharing is considered. This suggests that more investment is required.
- We have seen a steady growth in the levels of reactive maintenance expenditure required over time and falling replacement rates in areas of the asset base which are less critical to service delivery, or where asset lives are longer.
- There is evidence that the replacement rates of assets in the UK are lower than for other countries and declining depreciation rates in both water and wastewater imply that we expect assets to last longer.

In section 3.4 we explain that the past may not be a good guide to the future and it is likely we will need additional capital maintenance investment to meet Net Zero and improve service performance for customers in the future. For example, our demand management enhancement case (NES15) already needs this investment to reduce leakage in Essex and Suffolk.

In section 3.5 we highlight the important of demonstrating effective asset management so companies are spending their existing allowances wisely and highlight our recent independent assessment against AMMA which places us in the top cohort of companies with our performance between ‘competent’ and ‘optimising’.

Section 3.6 presents our evidence on customers’ views of asset health. Generally customers recognise the importance of maintaining a healthy asset base when the issues and risks are explained to them, they want us to adopt an approach that goes beyond ‘fix on fail’ but also ensure that investments do not increase bills unnecessarily at this difficult time.

Both the CMA and the Scottish water regulator (WICS) have considered related issues. WICS in its SRC21 chose to provide a material uplift in capital maintenance allowances reflecting similar concerns (see section 3.7).

Finally, we explain that to address these issues will require much wider change to the regulatory framework as is evidenced by an exchange of open letters between Ofwat and the National Infrastructure Commission (NIC). We fully support those changes and given the need for wider reform we focus entirely on only those ‘no regret’ investments that are in customer’s interests.

3.1. THE IMPORTANCE OF LONG-TERM ASSET HEALTH

a) Is there evidence that the proposed enhancement investment is required (ie there is a quantified problem requiring a step change in service levels)? This includes alignment agreed strategic planning framework or environmental programme where relevant.

Water and wastewater companies provide essential services – without safe clean water to drink and wash with or without effective wastewater services customers and citizens would quickly find themselves in major public health concerns. It is partly for this reason that water companies have legal obligations to provide clean and wholesale water and to effectively drain the areas we serve, and our regulators are also **under legal obligations** to ensure that we can 'fulfil our functions' (under the Water Industry Act 1991).

We provide these services through a vast and complex network of assets - in the case of Northumbrian Water, our pipe network would extend around the globe end-to-end and our assets include complex treatment works, large civil structures such as reservoirs and mechanical and electrical assets amongst many others. Water companies also maintain assets with some of the longest lives of any sector, with some of our assets having an engineering life of more than 100 years. Companies need to both maintain these assets so that they are healthy and also replace them when they reach the end of their useful lives.

Failing to invest and maintain these assets, particularly for service critical assets, could mean service failures for customers. For example, if a water treatment works serving a local town failed catastrophically then without either an alternative or emergency supply customers could face a significant interruption to their essential water supply. These failures, if they were to occur, could be catastrophic with material impacts on customers. Recent global examples of the failures in New Zealand, for example, provide a pertinent reminder of the risks that could occur if insufficient investment is being made and companies are not maintaining their assets efficiently and effectively. It is therefore essential that water companies are managing their assets effectively and investing sufficiently to keep them in good working order.

3.2. CASE STUDY: NEW ZEALAND'S WATER CRISIS

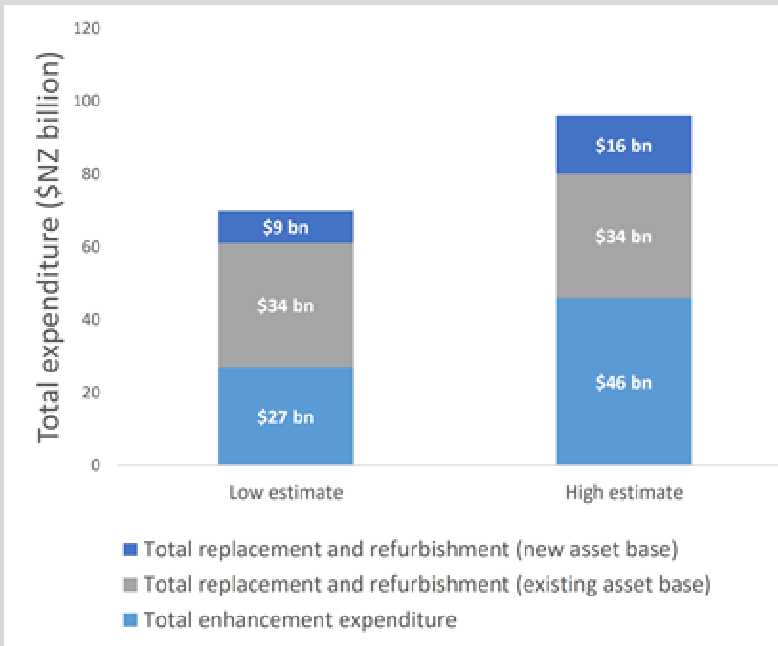
In 2016 four people died and 5,000 fell ill after sheep faeces contaminated Havelock North's water supply. This tragic incident resulted in a government enquiry that identified systemic failure among water suppliers to meet the high standards required for the supply of safe drinking water to the public. The inquiry revealed that 20 percent of water supplies were not "demonstrably safe".[6]

As a result, the 'Three Water Review' was commissioned to investigate how to improve the regulation and supply arrangements of drinking water, wastewater and stormwater (the three waters) to better support New Zealand's

[6] '**Report of the Havelock North drinking water inquiry: stage 2**', NZ Department of Internal Affairs, December 2017, p.232, p.244.

prosperity, health, safety and environment. The review identified a growing infrastructure deficit across all three areas as shown in FIGURE 3.

FIGURE 3: ESTIMATED ENHANCEMENT AND EXPENDITURE GROWTH BETWEEN 2020 AND 2050 REQUIRED TO MEET CURRENT STANDARDS IN NEW ZEALAND



Source: Three Water Reform Programme March 2021 Local Government and Iwi/hapū engagement

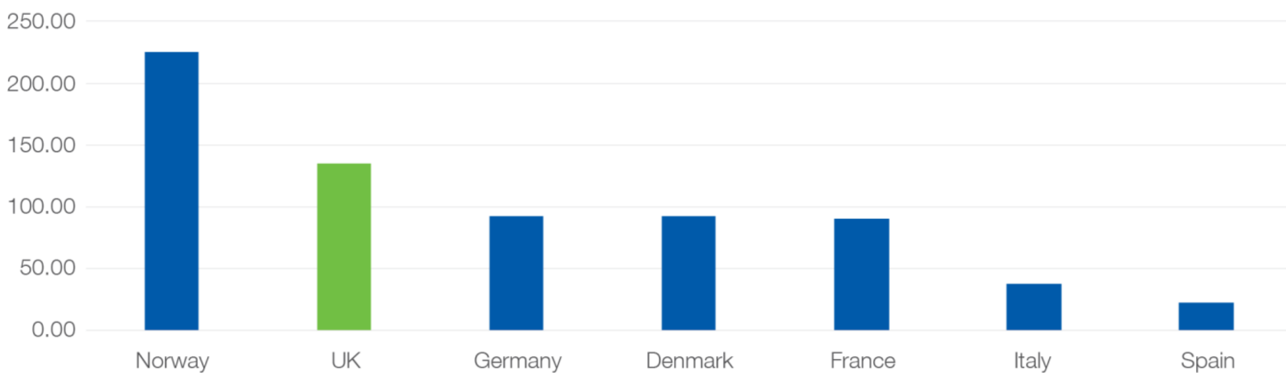
The required investment in infrastructure amounts to NZ$2.3 billion to NZ$3.2 billion annually or NZ$70 billion to NZ$96 billion over the next 30 years – potentially doubling the required spend relative to the baseline council expenditure of NZ$1.5 billion annually, or NZ$45 billion over the same period.

Customers pay significant sums in their bills to fund capital maintenance. For Northumbrian Water, we spend around £170m every year on the maintenance of those assets and this equates to £90 per customer or around 24% of the bill. It is critical that we ensure that companies are not mismanaging these assets or that investment and that it is being undertaken efficiently.

3.3. LEVELS OF CAPITAL MAINTENANCE SPENDING ARE UNLIKELY TO BE SUSTAINABLE

Across the UK levels of investment in water and wastewater infrastructure are higher than many other European countries and there was a marked increase in levels of investment in water and wastewater infrastructure after the sector was privatised.

FIGURE 4: ANNUAL INVESTMENT RATE IN BOTH DRINKING AND WASTE WATER INFRASTRUCTURE PER CAPITA (5-YEAR AVERAGE)



Source: EurEau, 2021

However, we are concerned that there is still insufficient investment in capital maintenance across the water sector in England and Wales and we discuss the evidence for this concern in the following sections.

3.3.1 Historical levels of capital maintenance spending are not close to the levels implied by the lives of the asset base we manage

We carried out a systematic assessment of the assets we hold in different ‘classes’ or ‘types’ against an engineering view of asset lives and the required replacement rates, and compared this against the levels of historical investment in those asset classes. This is a “bottom-up” assessment of the level of investment that – on initial examination – we should spend on replacing assets as they move beyond their asset lives, versus what we are actually spending now. This approach benefits from a detailed assessment of the asset base against the age of that asset base and so provides some rigour as to the efficient level of investment using asset age which is likely to be one key driver of failure. However, there may be other drivers of asset replacement or failure, or opportunities to extend asset lives and over time and some assets might be used at different capacities as growth and demand vary across company regions over time.

This was broadly the approach taken by the Water Industry Commission for Scotland (WICS) in its recent Strategic Review of Charges (SR21). Under that approach, WICS have taken the view in their final determination that Scottish Water, which is a water company operating in a demonstrably similar environment to companies in England and Wales and a neighbour of Northumbrian Water, has been underinvesting in the replacement of its assets in the past and delivered a substantial uplift in allowed costs for asset replacement. The allowances are subject to stringent controls to ensure that the company does invest in the maintenance of those assets.

The methodology applied in Scotland looked at the replacement cost of an asset class and divided this by its life expectancy to give long term asset replacement rates. We have sought to replicate the Scottish approach for our business. We applied the initial WICS methodology using readily available data with the results summarised in Figure below. Long life assets, such as dams and impounding reservoirs were excluded in line with the Scottish Water methodology as these were assumed to be repaired in perpetuity.

FIGURE 5: RESULTS FROM APPLICATION OF WICS METHODOLOGY

	Value (22/23 prices) £m	Life expectancy (years)		Replacement rate (£m/year)		Current annual spend (£m/year)
		Low	High	Low	High	
Water service						
Water resources	1,543	81	108	14	19	1
Raw water distribution	1,262	88	118	11	14	7
Water treatment	1,578	52	71	22	30	19
Treated water distribution	7,792	65	92	85	120	36
Wastewater services						
Sewage collection	13,518	60	86	156	224	25
Sewage treatment	2,664	43	51	52	62	27
Sludge treatment	569	66	94	6	9	12
Subtotal	28,927	60	83	347	479	128
Total (excluding longest-life assets)	15,024	56	76	197	268	110

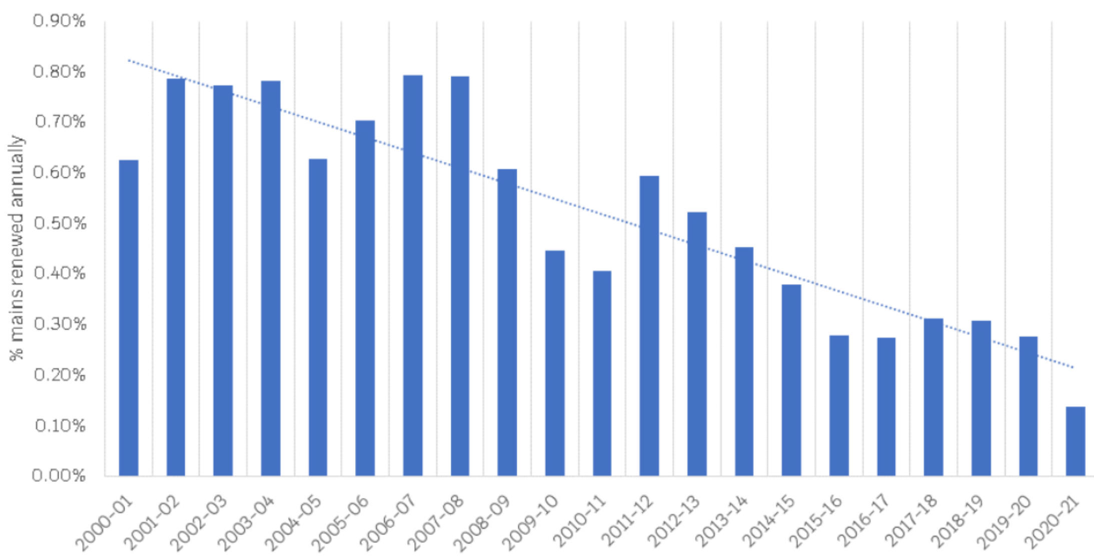
Source: NWL analysis as part of WICS Methodology working group

This work is imperfect but the analysis suggests the long-term replacement rate could be between £197m and £268m per year. We compared this analysis to our historical investment in replacement rates over the last 10 years in the same asset types. To be conservative, we also included maintenance costs to show that this classification could not be driving a gap with the long run replacement rate – without this the number would be lower. This indicated historical replacement rates in the order of £110m per year. This is around a half of the long-term requirements identified above. This finding is similar to the analysis undertaken by Scottish Water that supported their uplift in funding in SR21, which identified a need to increase spending by 80%-123% on historical levels[7].

[7] Scottish Water 2016/17 to 2020/21 capital maintenance spend outlined in https://wics.scot/publications/scottish-water/annual-return-regulatory-accounts/2020-21-annual-return/2020-21-g-tables , and increased capital maintenance requirements identified by WICS are outlined here: https://wics.scot/system/files/publications/Asset%20Replacement.pdf

The analysis also suggests that the larger gaps tend to be in those asset classes with longer lives including water mains and sewer networks whilst investment in more critical water treatment works and sludge treatment works are currently consistent with or slightly above the mid-point values implied by the replacement rate analysis. This is consistent with what we see internally through our management and governance of capital expenditure where scarce capital investment is consistently allocated to more critical asset classes and activities and longer-life assets receive less funding. At an industry level Ofwat has also presented similar information, for example in relation to mains renewal where they showed that industry wide rates of mains renewal had been falling over time.

FIGURE 6: ANNUAL MAINS RENEWAL RATES



Source: Ofwat cost assessment working group, [Capital Maintenance CAWG 28/09/21 (ofwat.gov.uk), p.12]

This provides a strong indication that current levels of spend are not sustainable in the long-run and that investment levels will need to increase to maintain service levels in the future. If these values (£174-236m versus £65m) were relatively close together then we might conclude that the difference is mostly down to inefficiency on the part of companies but with such a large gap, notwithstanding the fact that NWL ranks second on Ofwat's cost efficiency ranks and so is 'efficient' against that benchmark, it is not credible to conclude that this gap is down to inefficiency.

3.3.2 Totex and capital maintenance allowances have been spent in full

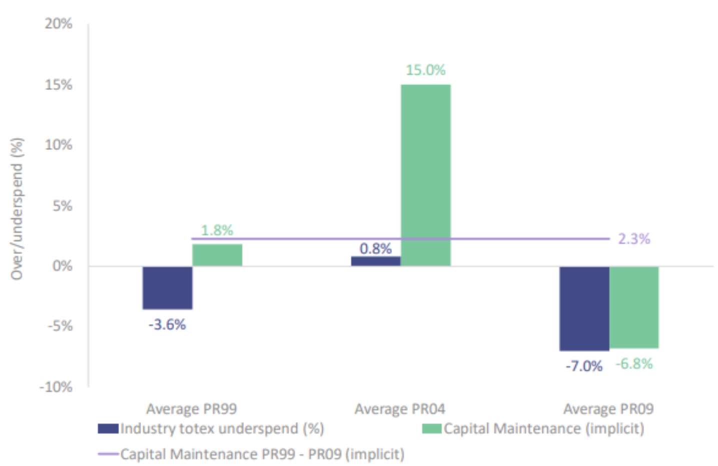
Companies are set cost allowances to deliver the service level outcomes and enhancement programmes over each five-year control period with cost sharing for over or under-spending. Within these total expenditure (totex) allowances they receive funding for capital maintenance activities. In the PR24 methodology these will be funded according to an updated set of Ofwat's 'base' (which represents funding for capital maintenance plus operating costs largely) totex models. Overall totex models first emerged in PR14 and 'base' totex models emerged in PR19 but companies have always been funded for a degree of capital maintenance expenditure since the first price controls were set following privatisation. In the three previous control periods these allowances were set separately and independently from other costs and so are more observable for other periods it is necessary to calculate an 'implied allowance' from the models.

In 2022, Water UK commissioned Economic Insight to consider these issues. As part of its work, **the report** examined the historical relationship between the allowances given to companies including overall cost allowances and specific capital maintenance allowances versus their outturn expenditure. The report highlights that:

- "[S]ince PR99 there has only been modest overall totex underspending of 2%. This modest level of underspend might be expected within the regulatory framework which incentivises companies to deliver services in a more efficient manner'. We note that the latest industry data share for 2022/23 suggests material overspending last year compared to allowances which, alongside previous overspends in the 2020-22 period, imply that the most likely outcome by 2025 is that over the past 25 years the sector will have overspent against its overall totex allowances".
- "[I]n the three price control periods where [capital maintenance allowances were set separately] companies have (on average) overspent on capital maintenance'. This analysis (represented in Figure below) shows that following PR99, PR04 and PR09, the three controls where allowances were set separately, the sector overspent on capital maintenance allowances in two of these controls and underspent in one."

From this and other analysis, Economic Insight **concludes that** "*companies have not been systematically 'cutting back' on asset maintenance and replacement by underspending their totex allowances' and that 'companies have actually prioritised capital maintenance (i.e. their asset maintenance and replacement activities) whilst staying just within their overall funding allowances*".

FIGURE 7: WATER INDUSTRY TOTEX AND CAPITAL MAINTENANCE SPEND (%) RELATIVE TO ALLOWANCES (2000 TO 2015)



Source: Economic Insight, 2022, Options for a sustainable approach to asset maintenance and replacement, figure 8

We have replicated Economic Insight's analysis for Northumbrian Water over the period 2000-2025 using historical information back to PR99 and the forecast information we provided to Ofwat for our anticipated spend to 2025. This is presented in Figure 8.

FIGURE 8: NWL HISTORICAL ACTUAL EXPENDITURE AGAINST CAPITAL MAINTENANCE ALLOWANCES (AMP 3-5) AND IMPLICIT ALLOWANCES (AMP 6-7) (17-18 PRICES, £M'S)

	AMP3	AMP4	AMP5	AMP6	AMP7	Total
Period	**2000-05**	**2005-10**	**2010-15**	**2015-20**	**2020-25**	**2000-25**
Maintenance Capex – Final Determination						
Water	458	428	583	537	599	2604
Wastewater	253	304	451	302	404	1714
Total	711	731	1034	839	1003	4318
Actual						
Water	443	471	468	547	652	2581
Wastewater	264	411	346	328	372	1721
Total	707	882	814	875	1024	4302
Overspend: Actual-FD						
Water	**-15**	**44**	**-115**	**10**	**53**	**-23**
Wastewater	**11**	**107**	**-105**	**26**	**-32**	**7**
Total	**-4**	**151**	**-220**	**36**	**20**	**-16**
Company share	100%	100%	30%	50%	55%	
Company share						
Water	**-15**	**44**	**-34**	**5**	**29**	**29**
Wastewater	**11**	**107**	**-32**	**13**	**-15**	**85**
Total	**-4**	**151**	**-66**	**18**	**14**	**114**

Source: NWL analysis of historical June Return and APR data and PR99, 04, 09, 14 and 19 FD information from Ofwat

This analysis demonstrates that by 2025, we will have slightly underspent our capital maintenance allowances on water (-£23m or less than 1% of total spend) and slightly overspent against our capital maintenance allowances for wastewater (£7m or less than 0.5% of total spend). In aggregate, we have spent within 0.5% of our allowances with a -£16m underspend. However, after cost sharing is applied to the various control periods, we will have actually overspent against our allowances by £114m. This is consistent with the analysis in 3.2.1 which shows that the sector, including Northumbrian Water, is not currently investing sufficiently in the maintenance and replacement of its asset base.

It also highlights the overspend that we are making in the current period. As part of our overall approach to risk management, we regularly report the risks to our asset base to our Board, and these are reflected in our corporate risk register and the annual risk and compliance statement to Ofwat. We also consider these risks as part of our resilience assessment (see A8 – resilience, NES09).

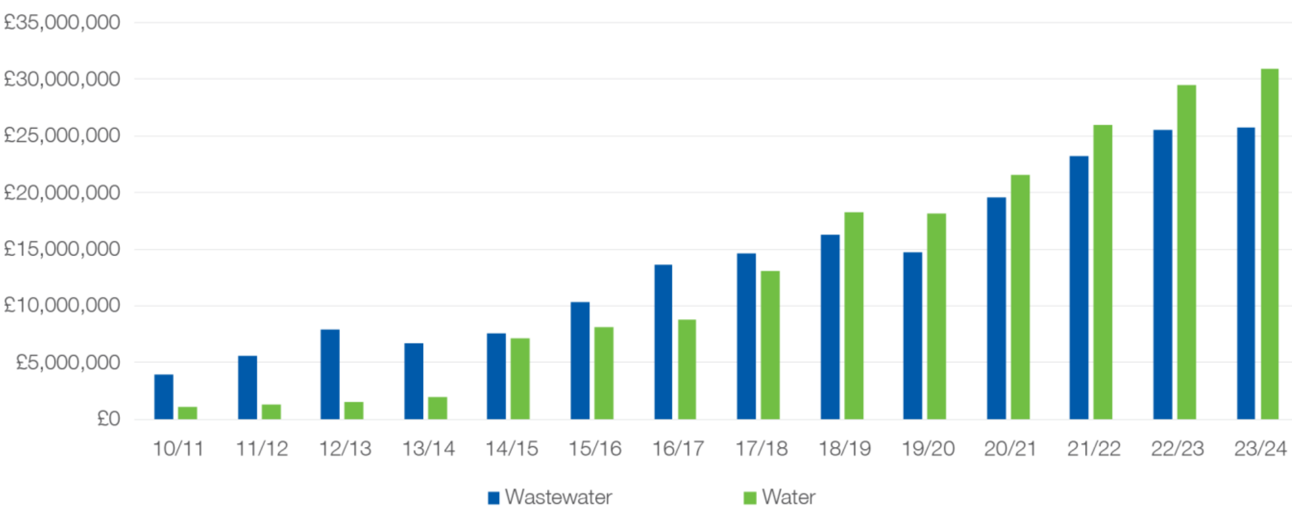
Across the 2020-25 period, we expect to overspend relative to our capital maintenance allowances by £20m. Some of this pressure is driven by atypical input cost inflation too, but the need for this overspend shows further evidence that capital maintenance allowances are insufficient.

As a result of pressures on the overall capital plan, we have been forced to divert investment away from some activities including, for example, mains renewal in the early part of the 2020-25 period. To date, we have been able to renew very little of our mains this AMP and we see growing pressure on the system in burst rates as well as challenges to leakage and ITS performance. In July 2023, our Board agreed additional funding for investment to replace a greater level of mains in the final two years of the period to increase investment to reach a 0.15-0.2% mains renewal by 2025 – this is a further overspend compared to PR19 totex allowances most of which will be funded by shareholders.

3.3.3 Reactive expenditure has been increasing

Wherever possible, we seek to plan future expenditure and maintenance activities by ‘proactively’ identifying investment priorities across the business. This helps us to better manage asset health risks and also often means more efficient costs, because it is often cheaper to proactively maintain and manage an asset that ‘reactively’ fix it when it fails. We monitor reactive maintenance expenditure across the business and over time we have seen substantial growth in this activity. Figure below shows that over time, our reactive maintenance activity has been consistently increasing across both the water and wastewater services.

FIGURE 9: NWL REACTIVE MAINTENANCE EXPENDITURE OVER TIME



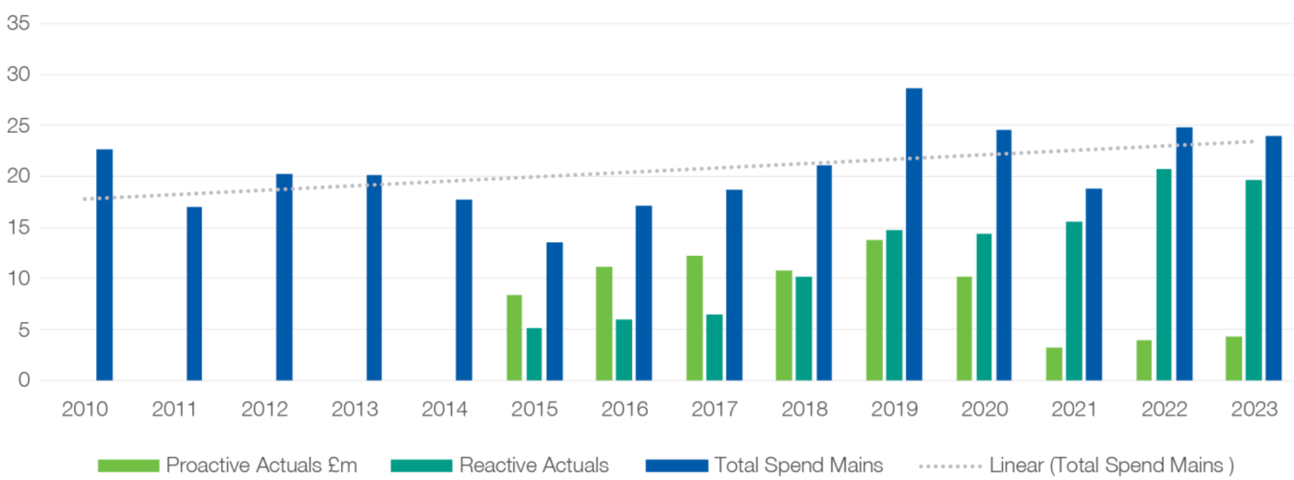
Source: NWL analysis of historical capital investment data

Although there are some cases where the most efficient outcome is to allow specific assets to run to failure, reactive maintenance expenditure – that is, spending money on assets that have generally already failed or are at the point of failure – is usually the 'last resort'. This is because the risk to service delivery to customers and the impact on our delivery of our legal obligations is greater. So, this expenditure is usually essential and must generally be prioritised over other capital expenditure.

However, a growing reactive expenditure requirement means that other important investments cannot be delivered within capital maintenance allowances. We consider a wide range of factors including service delivery and risk in deciding how to allocate capital investment and have expanded those decision support tools in the 2020-25 period through our service planning transformation programme (see A8 – resilience, NES09 for more details). However, we have increasingly found that the demand for capital maintenance and replacement outstrips the available funding.

For example, we can observe this move away from proactive to reactive activity in our water mains, which have some of the longest assumed asset lives of all the asset groups we manage (of around 100 years). Since completing the extensive AMP3/AMP4 S19 quality mains renewal programme, our overall expenditure on mains renewal has been relatively stable, as shown in Figure . This clearly demonstrates that our level of reactive spend is increasing at a higher rate than our overall level of mains expenditure, and if the upward trend in reactive spend continues, it will surpass the trend in our overall level of investment in mains renewal within AMP8. This helps to illustrate the immediacy of the problem we face and the need to increase investment in AMP8.

FIGURE 10: ANNUAL EXPENDITURE ON MAINS RENEWALS (£M'S) SPLIT ACCORDING TO REACTIVE AND PROACTIVE RENEWALS



3.3.4 Industry evidence of under investment in asset health

The broader industry evidence also suggests that we are not, as a sector, investing sufficiently in the maintenance and replacement of our assets. This includes:

- The asset base, represented by the RCV, shows a growing gap relative to maintenance expenditure.
- Sector wide work undertaken for Water UK also suggests that the sector is not investing sufficiently in the maintenance and replacement of its assets, including highlighting:
    - The relatively low replacement rate of water assets of the UK relative to other European countries.
    - The relatively old age of some assets across the sector given where information is available.
    - The declining depreciation rates across the sector which demonstrates that the sector is expecting assets to last longer.

A SECTOR WIDE STUDY ALSO SUGGESTS THAT THE SECTOR IS NOT INVESTING SUFFICIENTLY IN THE MAINTENANCE AND REPLACEMENT OF ITS ASSETS.

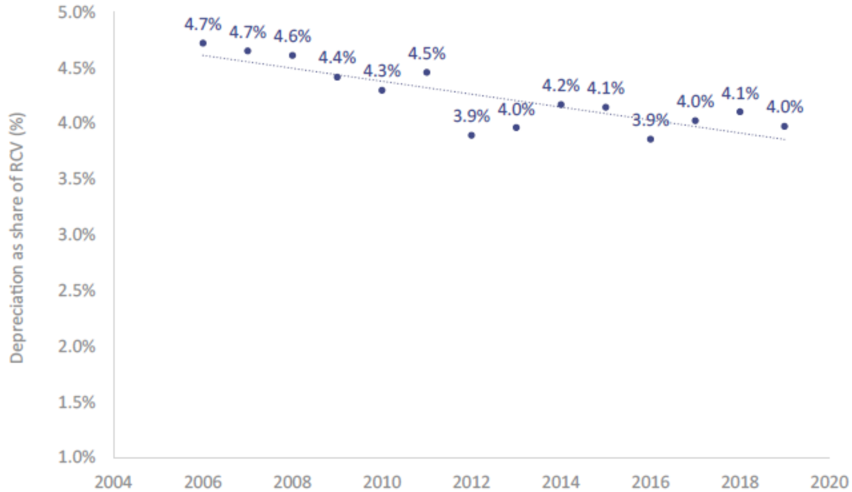
In 2022 Water UK commissioned Economic Insight to consider whether, and how, the regulatory framework at PR24 (and beyond) could be updated to encourage a long-term sustainable level of asset maintenance and replacement. The report concludes that:

> ***"the available evidence suggests that there is a need for a step-change in the level of asset maintenance and replacement at PR24 (and beyond) to ensure it is on a long-term sustainable path. In turn, this requires a step-change in the level of funding available for this through future price controls", Economic Insight, 2022***

The report also goes on to provide evidence that:

- There is no relationship between asset depreciation and totex over/underspend; nor is there any correlation between asset depreciation and returns earned. It concludes that the evidence is not consistent with companies systematically making 'cuts' (for example, by underspending their totex allowances) by extending the lives of their assets to earn higher returns.
- The rate of replacement of water assets in England (0.1% pa) is significantly below the European average of 1% - that is, 10 times lower. The average age of water mains in England is around 60 years, and there is a considerable "tail" of older assets, with 25% of assets more than 80 years old and 13% more than 100 years.
- The data for depreciation of water and wastewater assets from 2004 to 2020 overall shows a downward trend in the depreciation rates. For water assets, this decreased from 4.7% in 2006 to 4.0% in 2019 (a 15% decline); and for wastewater assets it decreased from 4.8% in 2006 to 3.6% in 2019. This implies that we are collectively expecting the assets to last longer on average.

FIGURE 11: INDUSTRY DEPRECIATION RATE ON WATER ASSETS, 2006-2019



Source: Economic Insight, 2002

Notes: Economic Insight analysis of 2006-2019 Annual Performance Reports. The depreciation rate has been calculated using the 'Depreciation Charge for year' for 'Water Service' divided by the 'Average RCV' for water assets for the year. The average RCV for water assets is calculated using the average RCV split between water and wastewater assets reported for PR14. The depreciation rate for the industry has been calculated using the aggregate 'Depreciation Charge for year' and the 'Average RCV' across the industry.

FIGURE 12: INDUSTRY DEPRECIATION RATE ON WATER ASSETS, 2006-2019

Source: Economic Insight, 2002

Notes: Economic Insight analysis of 2006-2019 Annual Performance Reports. The depreciation rate has been calculated using the 'Depreciation Charge for year' for 'Wastewater' divided by the 'Average RCV' for wastewater assets for the year. The average RCV for wastewater assets is calculated using the average RCV split between water and wastewater assets reported for PR14. The depreciation rate for the industry has been calculated using the aggregate 'Depreciation Charge for year' and the 'Average RCV' across the industry.

There are many reasons that might explain the trend in depreciation rate and the relative position of the English water industry to Europe for asset maintenance and replacement and age. The report concludes that "*the extent to which the water industry is an outlier relative to other countries is such that the data appears consistent with investment now being below the long-term sustainable average.*" This raises the question about how long into the future the water industry can continue to adopt approaches to maintain or further extend asset lives that already appear to be much longer than in other countries.

The evidence of historic replacement rates, asset age and depreciation trends support the need for additional allowances for asset replacement at PR24 and beyond.

3.4. FUTURE CHALLENGES ALSO IMPLY A NEED FOR ADDITIONAL INVESTMENT

The existing changes in climate and population growth are likely to create additional future pressure on water and wastewater assets in the future. The Environment Audit Committee **recently noted this too**, saying that "a step change in regulatory action (and) water company investment…is urgently required." Indeed, there are a number of significant examples here that could drive a need for material change in the future, many of which we discuss further in our **Long-Term Strategy** (NES_LTDS), for example:

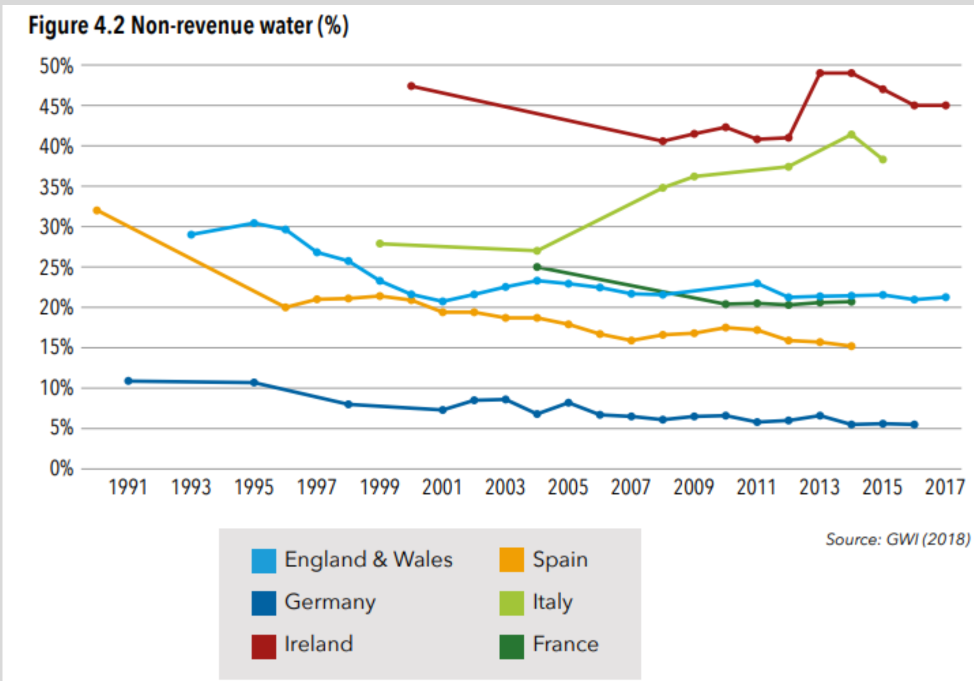
- **The move to net zero** – the sector is a major contributor to climate change and has set ambitious targets to reduce emissions and reach 'net zero' on operation emissions by 2030[8]. Ofwat and the Government also support reducing emissions in the near term. In order to achieve net zero, companies will need to fundamentally reform their asset base, replacing power and chemical intensive treatment technologies with more blue-green infrastructure[9]. Our LTDS sets out the expected costs of achieving net zero by 2050.
- **Achieving stretching service performance targets and maintaining security of supplies –** the sector has similarly set itself some ambitious targets to improve service, for example the sector is seeking to triple leakage reduction by 2030[10] and reduce leakage by 50%[11] and Per Capita Consumption to 110lpd by 2050. Reaching these service targets may require a structural change to the replacement or maintenance of assets. For example, a **Global Water Intelligence (GWI) market study** in 2018 examined leakage levels around the world and noted that reducing leakage to the ambitious levels seen in some other countries would likely require a material increase in the replacement rates of underground mains to match the asset lives of those locations.

[8] NWL has set itself an even more ambitious target of achieving Net Zero by 2027
[9] See: **https://www.water.org.uk/routemap2030/wp-content/uploads/2020/11/Water-UK-Net-Zero-2030-Routemap.pdf**
[10] '**Public Interest Commitment**' Water UK, April 2019, p.3.
[11] See **Leakage**, Ofwat website. Water companies committed to the 50% reduction from 2017-18 levels in a letter from Water UK to the Secretary of State on 17/10/2018. The reduction was a recommendation from '**Preparing for a drier future: England's water infrastructure needs**', the NIC, April 2018, p.13.

Impact of stretching service improvements on asset maintenance and replacement - leakage

The Global Water Intelligence (GWI) market study in 2018 looked at the percentage of non-revenue water compared to total distribution input. The England and Wales data is believed to include supply pipe leakage (as this is usual practice) and hence this is not a true comparator. That said, England and Wales are similar to France, with Ireland being significantly higher and Germany being at 5%. Germany has invested significantly in its network over the past 70 years and is also assisted by benign soils and favourable water chemistry when compared with the UK.[12]

FIGURE 13: NON-REVENUE WATER COMPARISONS ACROSS EUROPE



Indeed, we are already seeing this in our own long-term Water Resource Management Planning to 2050. In order to achieve a leakage reduction of 40% in Essex and Suffolk from the current position where we have some of the lowest levels of leakage across the sector, we are already forecasting that we will need to invest more in mains renewal, this is explained in our demand management case (NES15).

3.5. THE IMPORTANCE OF EFFECTIVE ASSET MANAGEMENT

We recognise that any request for additional funding from customer bills at this difficult time will be unwelcome and that a critical question in the funding of any further capital maintenance investment will be demonstrating that we and other companies are managing our asset base and the associated capital maintenance allowances efficiently and effectively. It

[12] European Environmental Agency. (WQ06) Water use efficiency (in cities): leakage, 2009.

was for these reasons that we have always supported the introduction of Ofwat's new Asset Management Maturity Assessment (AMMA) framework as this gives confidence that companies are not seeking additional capital maintenance allowances due to inefficiency.

We are always seeking to improve our asset management approach and maturity and have a number of major programmes underway. We were one of the first companies to achieve the ISO 55001 accreditation in this area and have retained that accreditation since 2015. In our most recent assessment, we retained the accreditation with only one minor non-conformity where we had completed assurance of the asset management system using the AMMA framework and the assessor considered that the AMMA framework was not wide enough. The assessor highlighted our continuous improvement in our asset management maturity[13]:

'The recommendation is continued certification, the management system is showing improvement, increased maturity and effectiveness.

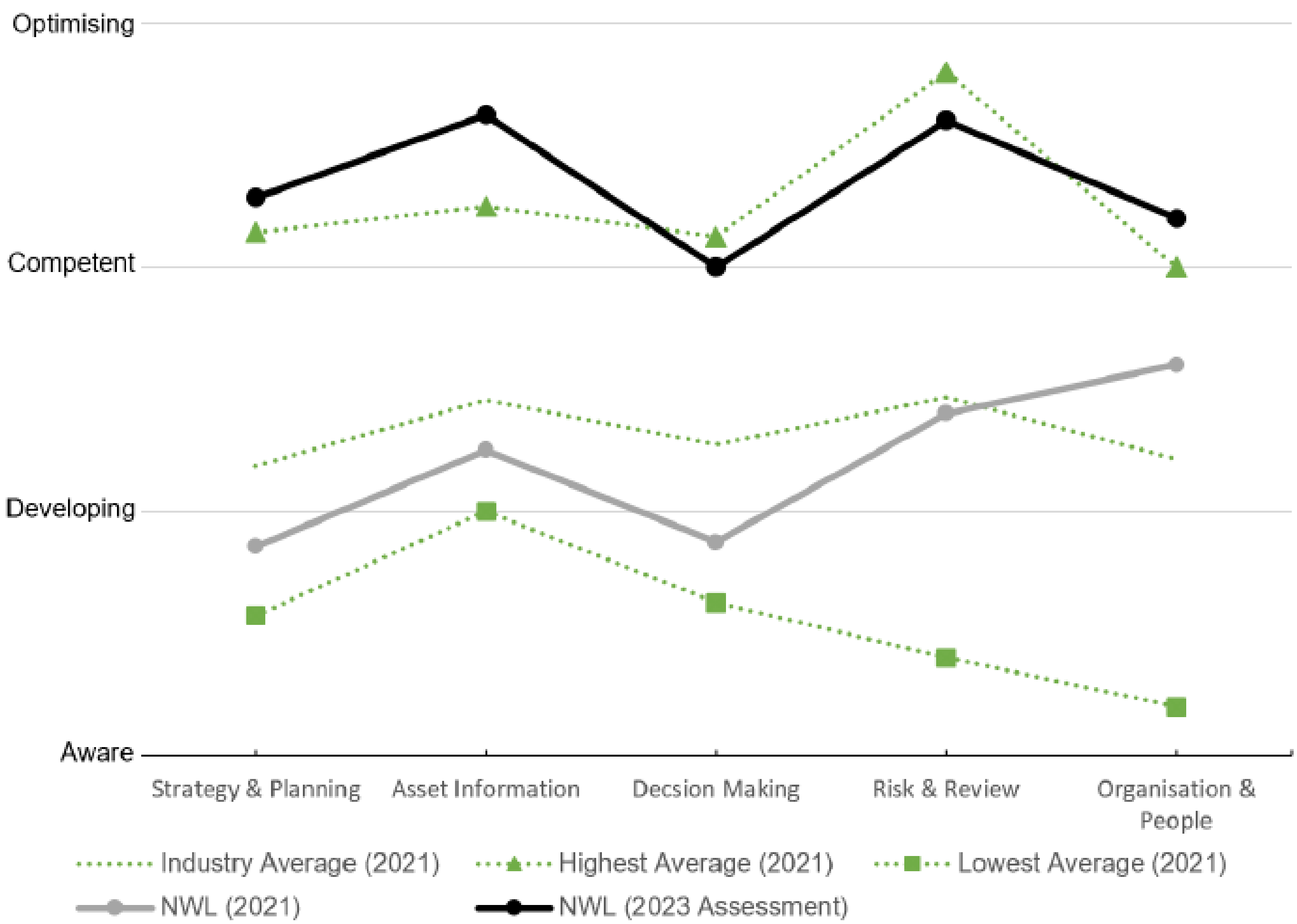
Employees are aware of the system and the level of buy in and understanding across the company has increased to a large degree. The system is now giving a higher level of benefit to the company and with the plans in place this benefit will only increase.

There are several areas where the company is making large improvement and changes for the better, these will be a focus for the next audit.' ANFOR ISO 55001 accreditation report, 2023

We sought to respond positively to Ofwat's original AMMA assessment in 2021 but we did not recognise the scoring when this was reported back. We wrote separately to Ofwat to raise concerns about the robustness of these assessments[14]. We subsequently engaged ARUP to complete a follow-up more detailed assessment of our AMMA scoring and their latest results are provided below.

[13] ANFOR UK LTD, 2023, Audit report Northumbrian Water Group
[14] 27 July 2021 letter, "NWL response to Ofwat Asset Management Maturity Assessment (AMMA) and associated company moderations and scoring"

FIGURE 1: ARUP NWL AMMA ASSESSMENT, 2021 AND 2023



Source: ARUP, August 2023, Northumbrian Water, Asset Management Maturity Assessment

This assessment, alongside the ISO accreditation provides robust evidence that we continue to manage our asset base effectively and efficiently. As part of the PCD associated with this case, we commit that we will retain an AMMA score of at least 'competent' throughout the AMP 8 period.

3.6. CUSTOMER SUPPORT FOR INVESTMENT NEED

d) Is there compelling evidence that customers support the need for investment (including both the scale and timing)?

Our customers expect us to maintain our asset health. In our "**Defining the Future**" research in October 2021, we asked customers about different topics and whether they wanted us to discuss this with them; or discuss it with someone else; or simply "deal with it". Customers clearly preferred us to "just deal with it" on making sure we provide a reliable supply of water and are resilient. For example, the report quotes one customer as saying "given that's what they provide is water they should know how to provide this constant supply of water so definitely in the just get on with it section". Customers said that although they didn't necessarily want us to actively engage with them on this topic, they wanted to make sure that "there are people who keep an eye on this", including Ofwat. Stakeholders shared similar views, saying that "it is a responsibility that they as a provider have to deal with, rather than have to consult with stakeholders on".

However, it was still important to make sure that we understood and included customer views in our decision making in this area – particularly as we developed our understanding of the need for increased investment in 2025-30. We discussed resilience and asset health in particular with customers throughout our customer engagement programme for PR24, presenting options for investing more in asset health at treatment works and service reservoirs – or going further, and investing now in other areas such as increased mains replacement. This has helped us to develop and refine this enhancement case.

In our **People Panels in November 2022**, we presented customers with some alternative approaches to thinking about asset health and asked them to discuss these:

- A "cost based" approach, where we would continue with our current level of capital maintenance. Customers who supported this were cautious about spending money before it is necessary and thought that the future is uncertain – it was not always clear that we needed more investment in asset health now, and what the impacts of specific investment would be. They thought that it was more important to keep bills low.
- A "risk based" approach, where we would invest now to tackle the biggest risks over the next few years. Customers who supported this wanted to prevent costs and problems escalating in future years and said that the same work would likely cost more in the future (similar to house repairs versus rebuilding).

Our customers described this as "a dilemma between a short-term fix and a long-term plan", and in this research 68% of people supported a more "risk based" approach. Customers asked us to develop a "hybrid, middle ground option" with some new criteria:

- We should invest where there is an immediate impact on service, and where we know exactly what work is necessary now – so we don't spend money before it is needed.
- If we delay work in some areas, we should focus on bringing down future costs – and we should only delay where we don't think this will lead to a major escalation of costs in future.

Customers also noted that affordability remains a major constraint, but they felt that asset health was an important investment.

"*We've talked about costs of repairs versus cost of maintaining infrastructure probably being increased, but potential disruption from things that break could potentially be more damaging than actual disruption due to repair or replacement. So, it being detrimental on a cost front and probably impacts to our everyday lives*" (online workshop 1, Suffolk)

"*I'd currently go for a middle ground option. Very depleted assets ought to be replaced, others that could be managed, so maybe a balancing act of what percentage of assets you deem you need a replacement you can actually afford to*" (Suffolk People Panel)

As a consequence of this research, we developed our "hybrid, middle ground option" in more detail. This was designed against these new criteria – that is, we should invest where there is an immediate impact on service, and where we know exactly what work is necessary now. We should not delay where we think there would be a major escalation of costs in future.

Using these criteria, we looked at different options. We concluded that investments at treatment works and service reservoirs would likely be the highest priority, with an immediate impact on service (for water quality, treatment works outages, and pollution incidents) and good information about the work that is necessary now (with as much detail as possible without a more invasive inspection). We could show that these investments would be cheaper now than replacements in the future.

We also concluded that water mains replacement would be another higher priority area. The impact on service levels is less clear for individual replacements, as it is more difficult to inspect these assets directly, but it was clear that the implied asset life was much too high, and the replacement rate would need to increase. The Water Forum challenged us to consider a higher replacement rate of 1% per year, as this more closely matched a realistic asset life.

"*If the rate can be increased to something closer to 1% (a 100-year implied life) then that would feel a more sustainable long-term rate. I am pleased to see NW considering this and would add my strong support for this because in the long-term it will be essential to sustainably achieve outcomes customers value…"*

"I am encouraged by the proposals being considered by NW in relation to mains renewal and urge that every effort should be made to develop and articulate a well-considered proposal in the AMP8 business plan". (Water Forum expert advisor, June 2023)

In our qualitative affordability and acceptability research, we asked customers about three possible phasing options for asset health. We described a "low" option, with no increased investment in asset health; a "medium" option, based on our estimated costs for treatment works and service reservoirs; and a "high" option with twice as much investment in 2025-30, bringing forward investments in increased mains replacement too.

Again, customers said that the maintenance of assets (and so ensuring a reliable service) was fundamental and highly important to them. Customers supported our proposed investment, with many customers asking us to go further to tackle potential future problems – that is, our “high” option with twice as much investment in 2025-30, bringing forward investments in increased mains replacement that had been planned for after 2030. This was because they did not want to leave a higher bill for future customers (rather than paying for investment now), and they felt that this could minimise problems in the network in future.

We spent much more time on this issue in our pre-acceptability research (January to March 2023), and this informed the development of our qualitative affordability and acceptability research. From our triangulation of all the research, we concluded that:

- Our customers support at least this level of investment in asset health – and many would support higher investment still.
- However, we did not think that increasing investment to a 1% replacement rate would meet the criteria developed through customer engagement (that is, we cannot show exactly where work is needed now or the immediate impact this has on service levels).
- In developing our long-term strategy, we identified some opportunities for innovation to reduce the costs of mains replacement and repair in future – and some further potential risks, such as the impact of increasing temperatures and drier soils. Delaying mains replacement would be likely to reduce the future costs, without a major immediate impact on service. This reflected customer concerns about making sure we can focus on bringing down future costs where we delay investment – and our asset intelligence and innovation work will support this over the next few years.
- There is a substantial increase in the investment programme for 2025-30 compared to previous price reviews – which creates risks around deliverability (see A6 – deliverability and past performance, NES07).
- Some customers were concerned about affordability, and so a higher investment would also exacerbate this.

As a result of these findings, we looked at potential options for balancing affordability against an increased investment in asset health. We explored the costs of a smaller uplift in mains renewal, as well as challenging our costs and implicit allowances for our investments in treatment works and service reservoirs.

This challenge led to us removing our enhancement need for service reservoirs and so allowing us to include some mains replacement without changing the overall level of investment for asset health – and so remaining close to the level of investment that our customers supported in our qualitative research. Our customers had challenged us to go further to tackle potential future problems including for mains replacement, and so we included this in our investment plans for 2025-30.

We have chosen not to increase our mains replacement rate all the way to 1% per year. This is because although we have sufficient evidence to show that increased maintenance is necessary for the asset class as a whole we do not know what the right efficient and economic long-term replacement rate is and we don’t consider that there is currently customer support for the increased level of investment that would be required to reach this level. A smaller investment would also help us to understand this need and impact, alongside a focus on understanding the future needs (through our asset intelligence programme) and bringing down future costs (through innovation).

Resilience, Asset Health and Long-Term Affordability

In 2018, we commissioned DJS Research to carry out qualitative engagement to understand customers' views on resilience, asset health and long-term affordability. Customers were asked whether NW should take a reactive, mid-ground or proactive approach to asset health. These were described as:

- Reactive- NW only fixes its assets if something goes wrong. This can lead to fluctuating water and sewerage bills and variable service for customers in the future.
- Mid-ground- NW aims to maintain the condition of its assets, providing stable performance. This leads to relatively stable customer bills and stable service.
- Proactive- NW aims to improve the condition of its assets. This can lead to higher customers' bills and potentially higher standards of service in the short-term and potentially in the long-term.

Not a single customer felt it would be ok for a water company to be 'reactive'. They expected a mid-ground to proactive investment position to be adopted. Reinforcing the preference for a 'mid-ground to proactive' approach is the fact the NW is seen to be providing an essential service and so to adopt a reactive investment position just wasn't deemed acceptable.

Discretionary Projects

In March 2018, we commissioned Explain Market Research to carry out customer engagement to understand customers' support for various resilience schemes. Complex and lengthy information, including costs and the impact on bills, was conveyed to customers before they voted whether to accept schemes. Customers were asked their views about seven different groups of resilience investments that would reduce risk of service failure and presented with bill impacts ranging from £0.03- £3.63 per annum on their bills- on average 92% of customers supported these investments (in a falling bill environment) with the lowest level of support at 84%.

Resilience is a difficult topic to engage customers on – as it is difficult to expect customers to take an informed view about future risks and the right balance between acting now and accepting risks for the future. **Research by CCW and Blue Marble** has found that one of the least appropriate areas for consumer research is "very long-term planning and future scenarios". has found that one of the least appropriate areas for consumer research is "very long-term planning and future scenarios".

This has proven difficult to research using quantitative surveys. For example, since Q1 2022 we have asked participants in our quarterly household tracking research which of 10 areas should be our business plan priorities. In four out of five quarters (Q1 2022 – Q1 2023), "*Better reliability by replacing infrastructure and doing more maintenance"* ranked 8th out of 10 priority areas tested.

However, it is important that customers are involved in making these decisions – and so we have used different research methods to improve our understanding. At PR19, we commissioned DJS research to understand customer views on resilience, asset health and long-term affordability (see text box above) – and customers felt that we should take a "balanced to proactive" approach. For PR24, our People Panels have helped to provide a more informed view about asset health and resilience, with customers having several research sessions to understand and discuss views on the long-term approach, their views on asset health, and then several iterations of specific investment proposals and choices. This increased level of detail has supported improved decision making for our asset health investments at PR24.

3.7. OTHER REGULATORS HAVE ALSO RECOGNISED THESE ISSUES

3.7.1 WICS approach in SRC21 determinations

The Scottish water regulator, WICS, also considered the long-term asset replacement rate for Scottish Water in its 2021 Strategic Review of Charges. During that review, and following significant work exploring the long-term asset replacement rate with Scottish Water, WICS concluded that Scottish Water needed to significantly increase levels of investment and support a faster rate of asset replacement. This was necessary to:

- Ensure sufficient investment to meet short and medium life asset replacement.
- Provide transition funding that would allow the efficient and effective replacement of all assets when the time comes.
- Ensure that Scottish Water is able to play an important role in helping Scotland achieve its target of net zero carbon emissions by 2045 and is appropriately funded to meet its asset replacement needs on a sustainable carbon neutral basis by this point.

It provided a material uplift to levels of capital maintenance and replacement funding with an increase expected to be around 80-123% over the long term[15].

3.7.2 Findings of the CMA during the PR19 redeterminations

In previous price reviews, Ofwat has set the allowed cost that companies can use to maintain their assets through a complex suite of econometric models - and this has continued into PR24. These models look back at the total expenditure (or 'totex') each of the companies have made in the past, including both capital maintenance expenditure and operating expenditure. They then try to establish an 'efficient' totex allowance for the next five years, accounting for certain differences outside of management control.

[15] Scottish Water 2016/17 to 2020/21 capital maintenance spend outlined in https://wics.scot/publications/scottish-water/annual-return-regulatory-accounts/2020-21-annual-return/2020-21-g-tables , and increased capital maintenance requirements identified by WICS are outlined here: https://wics.scot/system/files/publications/Asset%20Replacement.pdf

Ofwat has historically set the allowed costs at the level of the top quartile companies – that is, those companies who are most ‘efficient’ or have spent the least totex over the last period. Under this framework, where allowances are set at the levels of the least spending companies, there is a risk that companies’ allowances are insufficient. This risk is exacerbated where levels of capital maintenance may be quite ‘lumpy’ over time. So, for example, some of those ‘top quartile’ companies who are setting the benchmark may have been going through a relatively low period of capital maintenance expenditure or a ‘capital maintenance trough’ where fewer of their assets needed maintenance or replacement.

These issues were explored in an expert report ‘**Providing appropriate regulatory funding for capital maintenance activity: Ensuring capital sustainability and service resilience**’ in 2019, which noted that:

“It is less understandable that risk--‐based analyses of future capital maintenance requirements should seemingly play no part at all in its PR19 assessment of capital maintenance given the apparent variability and cyclicality of this activity.

“The obvious solution to this problem is one that Ofwat, the Competition & Markets Authority (CMA) and other economic regulators have all identified in the past, namely the triangulation of historical cost benchmarking with more grounded asset--‐based evidence.

“In our view, a price review in which the funding levels suggested by econometric models are cross--‐checked, when necessary, against engineering assessments is likely to produce more rounded and accurate overall funding allowances than a review in which lower quartile historical expenditure is simply rolled forward for another five years.

“This was also the CMA’s view in the 2015 Bristol Water case, and we note that other regulators also use such information even where (as in Ofgem’s case) there is the potential in a multi--‐company environment for sector--‐wide benchmarking.

“Against this background, we think it advisable for Ofwat to take account of forward--‐looking asset and engineering information as it considers companies’ revised business plans in the run--‐up to draft and final determinations.

“This might mean permitting companies to make special cost factor claims under a capital maintenance heading or through instituting a more generic process to enable the necessary cross--‐checking of econometric projections with company--‐specific information.

“The precise process is to our mind less important than that the work is undertaken to provide assurance to customers and government on service sustainability and resilience.”

Source: Providing appropriate regulatory funding for capital maintenance activity: Ensuring capital sustainability and service resilience, Dr Harry Bush CB and John Earwaker, May 2019

At the last price review, Ofwat showed that it was not the case that the companies setting the benchmark were operating in a 'capital maintenance trough' and the CMA in its PR19 redeterminations supported this position. However, this risk is still present in the current approach to cost assessment.

In particular, when future investment requirements are likely to be above historical requirements – as we consider is likely to be the case for the water sector – the risk that this approach will lead to underfunding is compounded.

In its redeterminations of the PR19 price controls the Competition and Markets Authority (CMA) recognised that this backward-looking approach may be increasingly problematic, saying:

> *'We acknowledge Anglian's and Northumbrian's argument that Ofwat's cost assessment is backward looking and that potential issues with capital maintenance may be forward looking. This is a complex issue, which, going forward, may become more important. We therefore suggest that Ofwat considers developing indicators to track this issue and to enable it to enhance its analysis with a forward-looking element that will assist in triangulating results from its econometric modelling of historic costs.'* Source: 'Anglian Water Services Limited, Bristol Water plc, Northumbrian Water Limited and Yorkshire Water Services Limited price determinations – Final Report', CMA, 17 March 2021, paragraph 4.2934.293

In Ofwat's consultation '**Assessing base costs at PR24**', December 2021, Ofwat explore how a forward-looking element could be incorporated into the setting of base cost allowances for PR24. They note:

> *'We are also open but cautious about the possibility of including business plan forecasts into our econometric wholesale base cost models if there is strong evidence to suggest that the historical period is not a good reflection of the future.'* 'Assessing base costs at PR24*', Ofwat, December 2021, p.18.*

We welcome the opportunity to work with Ofwat to ensure that the approach to base cost modelling is effective and allows for efficient costs. However, the approach for PR24 is now in place and cannot be easily changed. Ofwat also consider there is limited evidence to demonstrate why the future is different from the past. We do not agree that this is the case, and we explore this elsewhere in section 3.4.

3.8. BALANCING NEAR TERM IMPROVEMENT WITH LONG TERM CHANGE

Reflecting on some of these challenges highlighted previously, the National Infrastructure Commission (NIC) recently wrote to Ofwat in an open and public letter[16]. That letter highlighted that:

[16] https://nic.org.uk/correspondence/letter-to-ofwat-on-water-company-asset-management/

- To support its baseline report for the second National Infrastructure Assessment it had issued a call for evidence from water companies to which it had received responses from twelve out of fifteen companies.
- The data suggested that companies take different approaches to how they replace or repair assets but they were concerned that asset replacement rates need to be significantly higher than they are currently.
- But, based on the evidence, *'the Commission cannot make firm conclusions on what the appropriate level of replacement should be' and 'recognises that…Ofwat will not want to incentivise asset replacement when it is not needed'*.
- However, they were concerned that Ofwat's asset health metrics were '*lagging indicators'* and '*they do not on their own give insights into the future condition of assets because their only data point is the point of failure'* and that '*a more complete view of asset health in the sector would support a multi-AMP view of the investment required to maintain asset health and, consequently, service performance and reliability'*.
- The NIC welcomed the Ofwat AMMA framework and suggested that Ofwat should '*take a lead on asset health and…develop consistent forward-looking metrics for defining and measuring asset health'*.

We fully support the findings and direction of the NIC letter, which is closely consistent with the points we raised in our own asset health paper in 2022, and also our research findings with customers. This implies that levels of capital maintenance might need to increase significantly in the future but also rightly recognises that the long-term efficient and economic level of capital maintenance and asset replacement needs to be defined through further work. Our asset health enhancement case for PR24 has therefore sought to focus on 'no regret' investments including:

- certain civil assets on our treatment works, where comprehensive independent condition surveys demonstrate that some of those assets, which are critical to service delivery to customers, are in very poor condition and need urgent refurbishment or replacement that will cost more than we consider can be funded from base allowances; and
- targeted water mains renewal to increase the level of renewal in the 2025-30 period to a level where modelling suggests that it will support a relatively stable burst rate but would still represent a level of renewal that is clearly not going to exceed the long-term efficient and economic level.

4. TARGETING CIVIL STRUCTURES AND MAINS RENEWAL

- Given the need for further change to better address these challenges in the future, as we set our in section 3, we describe in section 4.1 why we are targeting civil structures and mains renewal. This includes an assessment of all of the asset classes we manage and whether the investment is stable, the assets are critical to service delivery and there is scope for deferment of the investment.
- In section 4.2 we describe the condition of the civil structures at our treatment works based on a comprehensive and independent survey exercise which highlights the condition of these assets. We go on to explain analysis we have undertaken to understand based on this survey evidence combined with other datasets to forecast how these assets will deteriorate in the future including across different construction material types. This helps us to identify how many of these assets may move to poorer condition grades in the future and over what timeframes.
- In sections 4.3 and 4.4 we provide some information about the nature of our water mains including their age and construction materials. We also present various evidence sources which might inform the important question of what the long term efficient and economic rate of mains renewal for our asset base should be (see section 4.5).

4.1. OUR APPROACH TO TARGETING INVESTMENT

b) 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)?
f) Is there compelling econometric or engineering evidence that the factor(s) identified would be a material driver of costs?

Our asset management transformation programme has enabled us to take advantage of opportunities to continuously improve how we manage our assets. This included gaining a better understanding of the health of our assets and then developing operations, maintenance and investment strategies to ensure we maximise value from our assets for the benefits of our customers and the environment.

As part of this, we commissioned a review from Jacobs to provide an assessment of our asset health position to help us to make sure that our approach is aligned with best practice. This review showed that our understanding of the asset health of civil assets at water and wastewater treatment works was lower than many other asset classes. This was because these are long-life structures with low failure rates, and so we did not inspect these as regularly as other assets, and we could not make as much use of analytics to understand future failure likelihood (as this needs a high number of assets to be effective).

In response to this, we carried out an extensive review of the criticality and health of all the civil structures at our treatment works - assessing wellness, fitness and life expectancy. This review process is now embedded within our business-as-usual process, and we can now track health and criticality in real time. These surveys revealed specific requirements for increased investment, as set out in section 4.2.

Although this identified a need in this area, we also wanted to make sure that we could identify and plan for similar increases (or any future reductions in needs that might help offset this). We wanted to make sure that we prioritised the areas requiring most urgent attention. To do this, we assessed our different asset classes against the following criteria:

- Stability of investment: Whether we expect stable investment in the short and medium-term to be sufficient to maintain service and risk.
- Asset criticality: The degree to which assets are critical to service, whether a fix-on-fail approach is viable and repairs can be actioned before service is impacted.
- Ability to defer: Whether programmes of investment could be deferred without unacceptable impacts to risk or intergenerational equity.

We carried out this assessment on our water and wastewater assets summarised in the subsections below.

4.1.1 Water assets assessment

The table below summarises the categories of assets on our water system.

FIGURE 2: WATER ASSETS

Asset class	Description
Boreholes, river intakes and raw water pumping	This category of assets includes pumping assets and associated civil structures to abstract groundwater from aquifers, surface water from rivers and then distribute water to storage and/or treatment. The function of these assets is frequently critical to the operation of the supply system, although in others there is redundancy in the source of raw water. These assets experience peaks and troughs of expenditure that balance out over the whole asset class. Much of the condition of this asset class can be observed by physical inspection during routine servicing or inferred from operational maintenance records mean that we have a reasonable degree of foresight of asset condition and deterioration.
Storage reservoirs	The category of raw water storage reservoirs includes a range of assets dam or embankment structures, emergency drawdown or spillway structures, outlet pipework, valves, actuators and other structures or plant required to operate and maintain the assets such as boat jetties or access roads. Storage reservoir assets are subject to periodic statutory inspection and remediation required by the Reservoirs Act. One effect of the Act has been to create a relatively steady and effective programme of maintenance to minimise the risk of catastrophic failure. Furthermore because of the programme of regular inspection the condition of assets is also well understood.

Raw water tunnels and aqueducts	Tunnels and aqueducts are structures which convey raw water from source to storage and treatment. The worst-case failure of this asset class is a collapse which blocks transmission, potentially disrupting supplies and creates a serious health and safety risk. We expect maintenance in this area to be relatively stable in the long run.
Water treatment works – civils	Our water treatment works each contain a number of different treatment processes, the combination depends principally on the time they were constructed and prevailing design standards and the volume and quality of raw water they are treating. The civil assets will benefit from the process unit redundancy where it exists but asset level redundancy is limited[17]. A common civil asset type is a reinforced concrete tank within which a water treatment process occurs. The failure modes for civil assets tend to be progressive in that the asset will show signs of degradation, then minor failure like leaks will occur and if left unresolved can eventually lead to assets being inoperable (i.e. drained down and removed from service) or a catastrophic failure such as a structural collapse.
Water treatment works – electrical, mechanical, SCADA	The shorter life mechanical, electrical and instrumentation/SCADA assets commonly have a binary failure mode[18]; they are operable or they are not. In some cases these assets are designed with a degree of redundancy, e.g. duty and stand-by pump sets. In others the whole process unit may be designed with redundancy to allow for example a rapid gravity filter to be drained for inspection, repair or media replacement.
Treated water pumping stations	This asset class includes pumping stations which lift treated water into supply from the outlet of water treatment works and booster pumping stations which distribute supplies in non-gravity fed sections of our network.
Trunk mains, distribution mains and communication pipes	The trunk mains asset base consists of the largest water mains which transfer water from treatment to network storage and from storage to local distribution mains which tend to be smaller in diameter. The typical customer connection is that a customer owned supply pipe connects to a company owned communication pipe which then connects to the distribution main. Mains typically have only two failure modes[19]; small cracks which result in leakage and large bursts which result in complete loss of transmission through the main. Cracks can progress to become large bursts. There are comparatively few failure events, therefore the understanding of the likelihood of asset failure is best summarised at cohort level based on the large volume of asset data we possess on these.

[17] Where redundancy does exist, it may be targeted at mitigation of impacts rather than allowing the process to continue to operate; for example bunds around fuel or chemical storage tanks to prevent pollution in the event of a tank failure.

[18] Although they may lose efficiency over their life too. Additionally, some failure may come with other consequences such as the worst cases causing equipment to catch fire.

[19] Some less commonly used materials such as PVC do have other failure modes including propagating longitudinal fractures.

Network storage	Network storage assets are those which store treated water once it has left our treatment works. They provide pressure to gravity fed systems, resilience from interruptions to supply and support efficient operation of the network; allowing pumping to be done during off-peak energy tariffs. Network storage generally comprises of two asset types; water towers which are built elevated above ground and service reservoirs which are typically sunk so that the roof is at ground level. The most common severe failure mode for network storage is water quality failures due to microbiological growth. The possibility of a catastrophic structural failure resulting in health and safety issues as well as flooding and interruptions to supply does still exist; but is extremely remote. This is because network storage assets are routinely inspected, and any serious defects observed are remediated before the reservoir is returned to service. This programme of inspection is required for all reservoirs designated by the Reservoirs Act 1975[20]. The findings from a previous inspection will be used to determine the date of the next inspection.
Network ancillaries	This asset class includes assets which are part of the distribution network but are not part of the other asset classes. This includes pipe bridges, zonal and district meters, air valves, other network valves and hydrants. These assets are disparate, and each will have their own failure modes – for example, valves may seize, meters may under-record or stop recording all together and pipe bridges may leak. Pipe bridges in critical locations such as across railways are routinely inspected and are remediated when in poor condition. The meter stock will tend to unrecord diluting the knowledge of flows in the network as it ages before it eventually stops recording, this is relatively predictable; failures can also be detected quickly where meters are connected to telemetry systems. A strategy of age-based replacement of network meters will keep expenditure steady and forecastable.

We then assessed these asset classes against our criteria for identifying the need for capital maintenance to be prioritised and increased within AMP8 as summarised in the table below. The colour classifications indicate:

- Stability of investment:
  - Green – we expect maintenance expenditure in AMP8 to be, at a broad level, consistent with historical levels.
  - Yellow – we expect a degree of ‘lumpiness’ of maintenance expenditure in AMP8 but that it will be balanced back towards historical averages over the long-term.

[20] The predecessor to the 1975 Act was the Reservoir Act of 1930 which was enacted shortly after two reservoirs failures which did lead to fatalities. Since the 1930 act came in to force there have been zero fatalities due to catastrophic reservoir failures in the UK.

  - Red – we expect a significant need to increase maintenance expenditure in this asset class in AMP8 and we expect that requirement to be consistent or trend upwards in the future beyond AMP8.
- Asset criticality:
  - Green – sufficient redundancy/resilience exists in the asset class to allow continued operation through a reactive 'fix on fail' approach.
  - Yellow – a mix of proactive maintenance, planned response to failures (for example, ready supplies of spares) and 'fix on fail' is required to efficiently manage service.
  - Red – some asset failure modes have the potential for catastrophic consequences across the entire asset class and asset condition must be well understood and actively managed to avoid catastrophic failure.
- Ability to defer:
  - Green – the likelihood of failure / asset condition allows other priorities to be pursued in the medium-term future.
  - Yellow – asset condition and deterioration can be better understood at cohort rather than individual asset level and there exists a degree of short-term resilience (perhaps via less efficient temporary works) which creates the ability to schedule maintenance and replacement.
  - Red – asset failure (or identified near failure) leads to immediate permanent repair.

FIGURE 3: ASSESSMENT OF WATER ASSET CLASSES

Asset class	Stability of investment	Asset criticality	Ability to defer
Boreholes, river intakes and raw water pumping			
Storage reservoirs			
Raw water tunnels and aqueducts			
Water treatment works – civils			
Water treatment works – electrical, mechanical, SCADA			
Treated water pumping stations			
Trunk mains, distribution mains and communication pipes			
Network storage			
Network ancillaries			

This revealed **three areas** where we do not expect stable investment to be able to maintain service and risk:

- **Water treatment works civils** - where we see increased future capital maintenance requirements as set out in section 4.2.
- **Water mains** - where current renewal rates are not sufficient in the long run to maintain risk and service as set out in section 4.3.

- **Network storage assets** - where some of our structures have design and materials issues that require addressing in order to maintain high quality services. We discuss this further below.

Civil structure assets need to be prioritised for 2025-30 because of the criticality of these assets - for example, a structural failure could lead to a long interruption or pollution incident. Water mains are less critical to service levels but, due to their large volume, will have a larger impact on future generations if they were deferred.

CONCERNS OVER NETWORK STORAGE ASSETS

As described above, our review of our asset classes revealed some issues with our network storage assets, which are mainly service reservoirs. These issues are about:

- The suitability of materials used in aged service reservoirs;
- Single compartment network storage assets which are critical to supply; and
- Pipework design leading to short circuiting of reservoir mixing.

We discuss each of these issues in more detail in the table below.

FIGURE 17: OUR WATER STORAGE CHALLENGES

Issue	Description
Suitability of materials	Network storage assets are typically either made from reinforced concrete, grouted masonry / brickwork, steel or glass reinforced plastic (GRP). Masonry and brickwork reservoirs are non-preferred materials within our asset standards as their surfaces offer greater opportunity for microbiological growth causing water quality failures. We have seen evidence of this with water quality failure rates of 2x to 3x times higher for storage of masonry construction than other materials over the period January 1996 – January 2023. We are starting to see reservoirs reaching an age and condition where they are becoming uneconomic to repair. For example; Ryhope service reservoir (of brickwork construction built in 1870) was spray-lined with concrete. When we inspected Ryhope, we found that lining was already significantly degraded with sizeable cracks. To return the reservoir to service we then installed a welded plastic liner, but this faster than expected deterioration is due do the underlying asset condition and demonstrates that further remediation and repairs will be uneconomic. With the age and condition profile of the existing asset base we are expecting this to need to increase in future AMPs, and the oldest reservoirs we operate are primarily of masonry construction. This means that these reservoirs will need to be replaced on a significant scale to avoid water quality issues.
Single compartment network storage assets	Single compartment network storage is in assets which are critical to supply. This combination makes it very challenging to drain the reservoir to allow safe entry and effect a full inspection. There is not sufficient redundancy due to the lack of a second compartment or suitable storage elsewhere in the network to maintain supplies. This necessitates a temporary solution such as tankering supplies or temporary pumping equipment to enable an inspection. Even in normal conditions these assets are creating a weak point in the resilience of the supply system. We have identified 26 network storage

	assets of this type. To address these issues on single compartment assets we would seek to install dual cell compartments.
Pipework design	Short-circuiting of reservoir mixing. The longer water stays in the supply system the more the effectiveness of the chlorination to suppress microbiological growth degrades. The inlet and outlet pipework arrangements in some reservoirs lead to the water most recently added to the reservoir being the first water taken into onward supply. This results in some water being retained in the reservoir much longer than planned and increasing the chance of microbiological growth and resulting water quality failures. With current computational fluid dynamics (CFD) simulation techniques it is possible to design inlet and outlet pipework to prevent this issue. We have identified 47 reservoirs at a high risk of short-circuiting[21]. We have seen evidence of this with water quality failure rates of 1x to 3x times higher[22] for reservoirs identified as high risk for short-circuiting compared with other reservoirs over the period January 1996 – January 2023. To address this issue, we ultimately seek to address this pipework design to avoid the issue arising in future.

We are currently still reviewing our asset standards and policy and our long-term investment plans for network storage assets. However, we expect that our future plans will include the following:

- A programme to **replace masonry reservoirs** phased over multiple AMPs, with the three highest priority sites identified as Ryhope, Spring Hill, and Caister.
- A programme to remediate inspection and resilience issues caused by **single compartment critical reservoirs**. This might include building additional compartments on site, by separating the existing compartment, building storage elsewhere in the network, rebuilding the reservoir entirely or other innovative solutions. A programme to replace all these reservoirs might cost upwards of £100m over multiple AMPs; but we expect to be able to plan a more efficient programme aligned to customer interests. Our highest priority concerns are two sites[23] which have been identified by the DWI as inoperable:
    - Westerton – commissioned in 1925 with a single cell design of reinforced concrete and a storage capacity of 1.5 million litres. It has had two water quality failures in the period since January 1996. Replacement of the asset is estimated to cost £4.3m.
    - Whittington Hill – commissioned in 1962 with a single cell design of reinforced concrete and a storage capacity of 710,000 litres. It has not had a water quality failure in the period since January 1996. Replacement of the asset is estimated to cost £3.6m.
- A programme to resolve the issues on **short-circuiting**. This may include a complete suite of CFD simulation models for all reservoirs to help confirm issues and identify and test potential solutions. The individual practical solutions most likely will feature relocating inlet and outlet pipework.

[21] Of these one is also of masonry construction and a further six are of single compartment design and are critical to supply.

[22] Failures at high-risk reservoirs is three times higher than other assets when normalised by storage volumes and equivalent when normalised by number or storage compartments.

[23] Three in total but this includes Spring Hill which is also a priority on grounds of it being a non-preferred material.

4.1.2 Wastewater assets assessment

For wastewater we considered each of our asset classes as summarised in the table below.

FIGURE 184: WASTEWATER ASSETS

Asset class	Description
Gravity sewers and sewer structures	The primary distinction in this asset class is between catchments in which foul sewage and surface water are separated and those which have combined sewers which take flows from both foul and surface water. Smaller sewers into which individual household drainage flows are typically constructed from vitrified clay[24]. Larger sewers which collect the upstream flows of many smaller sewers are commonly constructed from masonry. The expected life span of vitrified clay pipes as gravity sewers is commonly accepted to be longer than 100 years and estimates of 200-400 years are not uncommon[25]. Crucially these estimates of lifespan are generally longer than those estimated for ferrous water mains; we do not observe the same immediacy to accelerate programmes of age/condition-based replacement in the gravity sewer network that exists for the treated water network. We do not believe that deferring the rollout of any potential replacement programme for gravity sewers until AMP9 at the earliest will create disproportionate impacts on inter-generational equity.
Sewage pumping stations	Sewage pumping stations (SPSs) support the transfer of foul, surface and combined sewerage to treatment works where topography or distance make a gravity drained system unachievable. A typical SPS consists of a wet well structure of reinforced concrete and either a dry shaft which houses pump motors or a submersible pump setup. Pumps might usually be configured in a duty / assist arrangement where assist pumps can provide additional capacity required during storm events. The SPS will also likely have a basic SCADA setup with depth/level sensors and a PLC[26] which will automate the running of pumps to set levels in the wet well. The maintenance strategy and expenditure on MEICA equipment at our SPS is expected to be stable in future AMPs. We may experience similar issues with SPS civils that we are currently experiencing with our WTW and STW civils. We hope to perform a similar programme of inspections in AMP8 for our SPS sites that underpins this investment case for WTW/STW civil structures to better understand future requirements. A particular issue with asset condition can occur in foul drainage catchments where due to either size or gradient of the catchment sewage spends a longer time in the collection network[27]. Over time, sewage will begin to turn septic; this occurs when sulphate reducing organisms in the absence of oxygen reduce sulphates in the sewage to hydrogen sulphide which then converts to sulphuric acid when it comes into contact with air. Sulphuric acid will accelerate the corrosion of concrete structures such as sewage pumping stations wet wells.
Rising mains	Rising mains are pipes which take the pumped sewage from a pumping station to connect it to either the sewage treatment works or a separate section of the gravity sewer network.

[24] Other materials with other asset failure modes such as pitch fibre sewers do exist although are much less prevalent.
[25] The use of clay pipes has dated back thousands of years and evidence of systems installed more than 200 years ago still being in service still exist; https://www.ncpi.org/assets/ncpi-engineering-manual.pdf

[26] Programmable logic controller
[27] Here size of the catchment refers to the length of sewer that sewage has to travel rather than land area drained although there does tend to be a correlation between both measures. Lower gradients in sewers result, all other variables being equal, in slower flow rates and hence sewage spending longer in the collection system.

	Unlike the gravity network these pipes operate under pressure and therefore are more commonly constructed from ferrous materials and can suffer from pipe bursts[28].
Sewage treatment works – civils	Our sewage treatment works each contain a number of different treatment processes, the combination depends principally on the time they were constructed and prevailing design standard, the volume of effluent they are treating and the characteristics of the water body they discharge to. Treatment processes typically include systems of civil, mechanical, electrical and instrumentation/SCADA[29] assets working together. The civil assets will benefit from the process unit redundancy where it exists for example a trickling biological filter to allow continued operation while one tank is drained for inspection or repair, but longer-term asset level redundancy is limited[30]. A common civil asset type is a reinforced concrete tank within which a sewage treatment process occurs. The failure modes for civil assets tend to be progressive in that the asset will show signs of degradation, then minor failure like leaks will occur and if left unresolved can eventually lead to assets being inoperable (that is, drained down and removed from service) or a catastrophic failure such as a structural collapse.
Sewage treatment works – electrical, mechanical, SCADA	The shorter life mechanical, electrical and instrumentation/SCADA assets commonly have a binary failure mode[31]; they are operable or they are not. Resolution of the failure can range from minor operational maintenance (e.g. restarting a tripped motor or clearing an obstruction) to complete replacement of an asset. In some cases these assets are designed with a degree of redundancy, e.g. duty and stand-by pump sets. In others the whole process unit may be designed with redundancy to allow for example a trickling biological filter to allow continued operation whilst one tank is drained for inspection or repair.
Sludge treatment centres – civils	A sludge treatment centre (STC) converts the sludge from the sewage treatment stream; either from an onsite sewage treatment works or raw sludge imports from other sites into a treated product suitable for disposal to land as fertilizer. It also seeks to recover energy from the sludge treatment process through generation and combustion of methane. Our sludge treatment centres primarily use an Advanced Anaerobic Digestion (AAD) process partnered with combined heat and power combustion engines to generate energy. The civil structures on our STC sites include the hardstanding that equipment is built on, pipework and the digester structures themselves. Much of the civil structures at our STCs are comparatively new as the legislation that prompted the adoption of sludge treatment processes[32] is much newer than the mass expansion of water and sewage treatment in the first half and mid part of the twentieth century. However, the chemical and thermal condition inside the digesters do tend to vastly increase the rate of deterioration when compared to more benign process such as final settlement tanks.
Sludge treatment centres – electrical, mechanical, SCADA	Because the age profile of our STCs is relatively aligned (see above) so the replacement cycle for MEICA equipment at STCs is also aligned and investment tends to exhibit material peaks and troughs.
Sludge transport and disposal	This asset class includes the on-site storage and the transport equipment (tankers, etc…) to transfer: • Raw (partially dewatered) sludge from a sewage treatment works without an integrated sludge treatment stream to a regional sludge treatment centre (RSTC). Including the facilities at the RSTC to receive incoming shipments.

[28] At weak points caused by a combination of age, condition, manufacturing defects or installation damage.
[29] Supervisory control and data acquisition
[30] Where redundancy does exist it may be targeted at mitigation of impacts rather than allowing to process to continue to operate; for example bunds around fuel or chemical storage tanks to prevent pollution in the event of a tank failure.

[31] Although they may lose efficiency over their life too. Additionally some failure may come with other consequences such as the worst cases causing equipment to catch fire.
[32] Urban Wastewater Treatment Directive

- Treated sludge to disposal to land.

The life cycle of much of this equipment (in particular the fleet assets) is relatively short, often one AMP or shorter. Therefore, the investment profile between AMPs is stable. We may experience more challenge if the availability of landbank decreases as expected in future, the initial expansion of fleets required to cope might be funded by enhancement cases but the maintenance which would come within the next or even the same AMP would require an increase in maintenance expenditure.

We then assessed these asset classes against our criteria for identifying the need for capital maintenance to be prioritised and increased within AMP8 as summarised in the table below. The colour grading is the same as described above for Figure 3.

FIGURE 19: ASSESSMENT OF WASTEWATER ASSET CLASSES

Asset class	Stability of investment	Asset criticality	Ability to defer
Gravity sewers and sewer structures			
Sewage pumping stations			
Rising mains			
Sewage treatment works – civils			
Sewage treatment works – electrical, mechanical, SCADA			
Sludge treatment centres – civils			
Sludge treatment centres – electrical, mechanical, SCADA			
Sludge transport and disposal			

This assessment shows that is just our civils for wastewater assets where we do not expect stable investment to be able to maintain service and risk. For the reasons set out in section 4.2 there is a need for increased capital maintenance for this asset category which, when combined with the high criticality of these assets for customers and the environment, mean that we consider increased investment in these assets should be prioritised for 2025-30.

4.1.3 Conclusion

In Section 0, we showed that the sector as a whole is not investing enough in asset health and that there will need to be increased capital maintenance in future, in order to maintain risk and service for customers and the environment. However, the precise long-run sustainable rate is not yet known. The approach to cost assessment needs to evolve to consider forward-looking aspects of asset health and criticality and we need to develop new asset health metrics to support these approaches so that it is clear what is being delivered for the increased investment.

However, it is not in customers interests to let these problems get worse and increase risk where there are clear, “no regrets” interventions that we can take now in areas where there are increased long-term needs. In 4.1.1 and 4.1.3, we explained why increased investment in treatment works civils and water mains renewal are the priority areas that meet this test, as there is clear evidence that current spend levels are not sustainable and will need to be increased in the future. By intervening now, we can reduce the risk of significant service failures and avoid unnecessary impact on future customers and intergenerational equity (by spreading the investment required over a longer period).

4.1.4 The PR24 methodology

In the PR24 methodology, Ofwat stated that for PR24 its aims “to include more of a forward look in our base expenditure assessment”. As part of this, Ofwat said that it was “open to considering company evidence on additional exogenous factors / cost drivers that require a step change in efficient capital maintenance expenditure through the cost adjustment claim process”.

For the reasons set out above in this section, we consider that there is a strong case for a step change in capital maintenance requirements to maintain the asset health of our civil structures. It is clear that overall levels of capital maintenance are not sustainable in the long run and that critical asset classes require additional expenditure now in order to maintain good asset health and resilience of service for customers.

Ofwat also stated that it was “concerned that current outturn rates [of mains renewal] are not sustainable and that companies are not undertaking enough renewals to keep up with deterioration”. For the reasons set out earlier in this section, we share this concern. The asset lives implied by current renewal rates across the sector are implausibly high. This can only mean that this is not a sustainable position and that renewals are not keeping up with deterioration. We think that PR24 should start to address this issue now to avoid larger problems in the future either in terms of increased risks to service or steeper increases in bills that could have been avoided by investment now.

Based on our analysis of investment stability, asset criticality and scope for deferment as well as recognising the position taken by Ofwat in the PR24 methodology, we have focused our investment on civil structures at treatment works and water mains renewal.

4.2. CIVIL STRUCTURES AT TREATMENT WORKS

The main investment driver for infrastructure assets is asset condition. As the condition of an asset, or the condition of key components, reduces over time, the risks to operational performance and customer service increase. The rate at which assets deteriorate is dependent on a variety of factors including operational regime, asset age and type, and service history, and the interaction between these factors and the deterioration of individual assets can be difficult to assess.

This enhancement case includes investment in the civils assets associated with water and wastewater treatment works – for example this is typically storm tanks, buildings, kiosks, chambers, overflow channels, treatment tanks amongst others. Annex 2 provides a series of case study examples of these assets.

4.2.1 Assessing asset condition

We have a well-established framework for assessing asset condition, based on industry standards and best-practice, and supported by an up-to-date set of survey results for our civils assets collected during 2020-23. Our framework uses a condition grading system based on the criteria set out by Ofwat in its asset inventory guidance from PR09, with the addition of sub-categories to support a more granular analysis.

These surveys, performed by expert civil engineers from Atkins, were based on visual inspection. Access to all areas was via existing infrastructure and all assets were operational during the survey (for example, tanks were not drained). Any issues identified were noted and a condition grade assigned, based on the condition grading system for civil structures, see Figure 20. The grading system is largely based on the criteria set out by Ofwat in its asset inventory guidance from PR09 (1 to 5), with the addition of sub-categories for the Average and Poor scores to enable more accurate identification of condition (for example, localised or structure wide).

We have previously provided Ofwat with an example survey report and explained our assessment in more detail, as part of our response to Ofwat's **operational resilience discussion paper**.

FIGURE 20: CIVIL STRUCTURES CONDITION GRADING SYSTEM

Grade	Description	General Meaning
1	Good	Modern Structure recently constructed or well maintained, in good condition, asset life greater than 20 years. Possible hair line cracks.
2	Fair	As Grade 1, but showing minor wear and tear, wider cracking (>0.5mm), localised honeycombing or flaking, no corrosion staining, sealant loss not affecting water tightness or structural integrity. Only normal maintenance expected in next 10-20 years, minor repairs required. Needs to be inspected again within 5 years.
3	Average	Functionally sound structure but affected by lengthy transverse or longitudinal cracking, rust staining, vegetation or minor leakage, some localised spalling of concrete or brickwork, e.g., lack of cover to reinforcement bars etc. No major work likely to be required within 5 years, minor repairs required to maintain current grade and not deteriorate further. Needs to be inspected within 5 years.
3a	Localized	Issues identified above are localized to one area of the structure only
3b	Structure Wide	Issues Identified above are structure wide, with the whole structure needing remedial works
4	Poor	Structure functioning but with problems due to significant leakage, cracking and spalling, loss of stability and/or deformation, corrosion substantially reducing the size of the structural members, exposed rebar, sealant loss which could lead to structural damage or leakage. Requires major attention within medium term (5 years).
4a	Localized	Issues identified above are localized to one area of the structure only
4b	Structure Wide	Issues Identified above are structure wide, with the whole structure needing remedial works
5	Very Poor	Completely derelict, corrosion such that significant reduction in size of structural members likely to cause overstressing or out of commission because unsafe to use. Requires major refurbishment or replacement within 12 months.

Source: Atkins inspections documents

The survey results are based on best available information for visible components. For example, for tanks this meant surveying the outside but not the inside of the wall, which gives a reasonable estimate of overall condition since many of the early signs of failure would be evident from one side only, such as deformation, cracking and leakage.

Figure 21 below shows the number and percentage of civil assets against each condition grade at the WTWs where condition surveys were carried out. It shows that the majority (89.4%) of civil structures are in average or better than average condition. However, that still leaves more than 10% (or 87) civil structures in poor or very poor condition. This means there is an urgent need for investment to refurbish or replace within the short to medium term (less than five years).

FIGURE 21: PERCENTAGE OF WTW CIVIL STRUCTURES IN EACH CONDITION GRADE

Grade	Description	Number of assets	Percentage
1	Good	46	5.7%
2	Fair	453	55.7%
3a	Average Localised	155	19.1%
3b	Average structure wide	72	8.9%
4a	Poor Localised	40	4.9%
4b	Poor Structure wide	44	5.4%
5	Very Poor	3	0.4%
Total		**813**	**100%**

Source: Our analysis of Atkins condition assessments

4.2.2 Analysis of asset condition

We then carried out a detailed statistical analysis of the asset inspection data, with the following objectives:

- To forecast the deterioration rate of WWTW and WTW civil assets in the next 15 years; and
- To quantify the number of assets reaching condition grade 4 in the AMP8 and AMP9 periods.

This statistical methodology is based on a multi-state survival transitional model which focuses on studying the time it takes for an event of interest to occur, such as the time for individual assets to deteriorate to the next condition grade or the time to failure. This type of “survival analysis” provides information about the distribution and probability of an event occurring at (or beyond) a certain point in time. It also assesses the impact of time-dependent covariates and the inherent uncertainty in the data which makes for a more realistic analysis.

This approach is particularly useful where the event of interest, in this case asset deterioration, can have multiple outcomes. These models are more complex which can make the analysis and interpretation of results more challenging, and generally requires a larger sample size to be reliable. The main benefits of the survival model are:

- We can forecast deterioration rates based on current actual condition – that is, we can model across all condition grades.
- It can account for fixed (such as the materials used) and increasing (such as the impact of increasing temperatures) hazards.
- It uses “probabilistic distribution”, that is, modelling the probability of an asset moving to the next grade.
- It can combine multiple parameters, such as material and usage.
- It does not rely on age groupings and can take into account individual assets.
- The framework allows for individual uncertainties to be applied.
- This is a well-established methodology, which has been successfully used to model condition on long-life assets. We therefore had the skills and knowledge needed to apply this approach to WTW and WWTW civil assets.

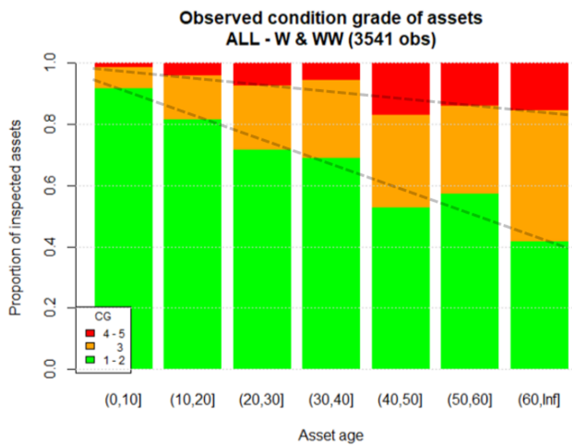
4.2.3 Existing asset condition

The statistical analysis looked at the observed condition grade against age and the impact of stratifying the data by material. It also looked at the effect of covariates, including usage, on the initial analysis and over time. Other possibilities for stratifying the data were considered and discounted at an early stage, such as using location of tanks and proximity to the coast, since no significant impacts were observed. We refined the analysis by testing the significance of covariates, by exploring “goodness-of-fit” measurements.

The main output from the statistical analysis is a picture of current asset condition – using the latest inspection data – showing the distribution of condition by asset age, material type and usage.

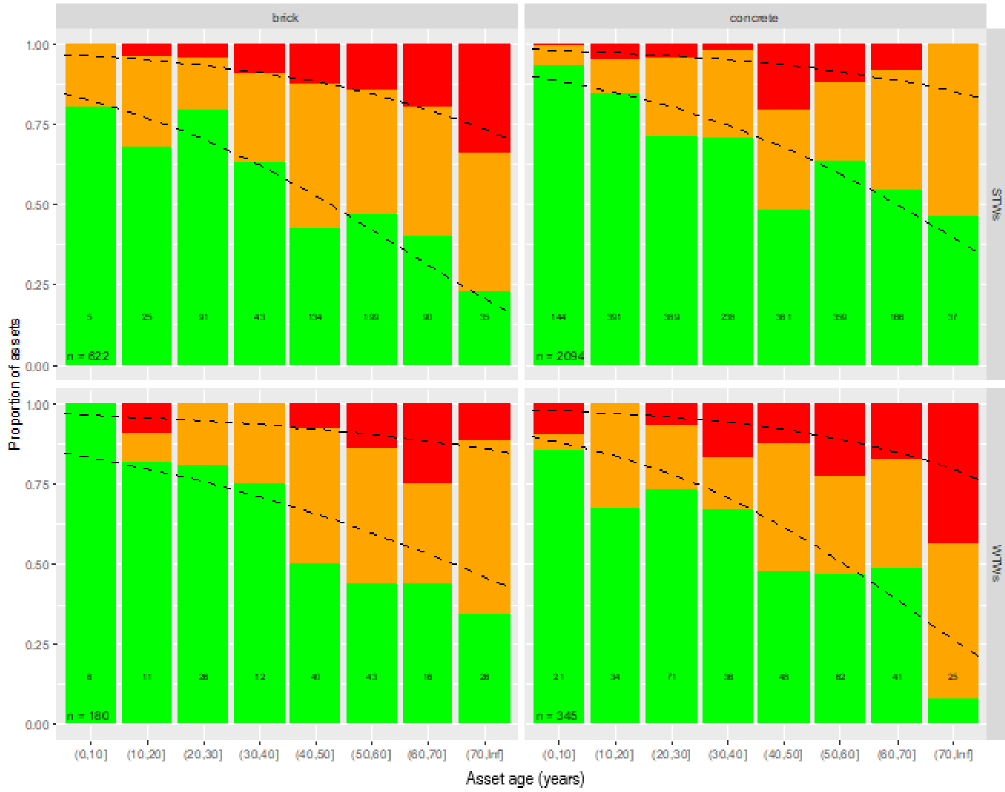
Figure 22 shows our analysis of all 3,541 inspections, as the proportion of assets in each condition grade split into 10-year bands. The older the asset, the worse the condition grade; and the proportion of assets in condition grade 3 and worse increases to about 40% after 60 years. This includes about 15% in grades 4 and 5.

FIGURE 22: DISTRIBUTION OF ASSET CONDITION FOR ALL TANKS



The following four graphs show the same information broken down by material (brick and concrete) and usage (water and wastewater) and the sample size for each group. The results provide useful additional data which will help to target further surveys and investigations into specific asset groups as part of detailed engineering design as needed.

FIGURE 23: DISTRIBUTION OF ASSET CONDITION BY MATERIAL AND USAGE

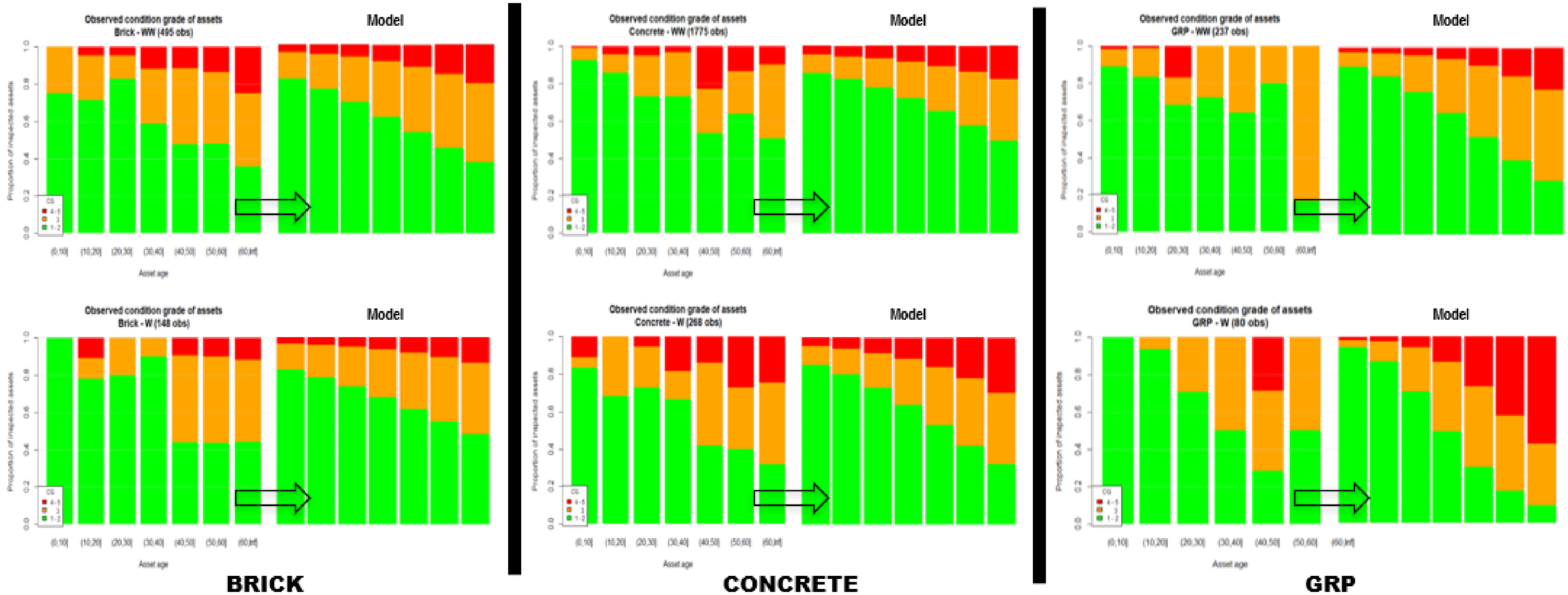


The general conclusions from a visual inspection of asset condition is that the results are a good representation of observed condition distributions for specific groups of assets.

4.2.4 Validating the statistical model

We validated the statistical model by using it to recreate the observed condition distribution based on asset inspections. The results are shown below as six pairs of graphs with the observed distribution based on inspection data on the left, and the calculated distribution based on model outputs on the right.

FIGURE 24: COMPARISON OF ACTUAL AND MODELLED DISTRIBUTION OF ASSET CONDITION



The fit of the survival model to the observed data is satisfactory: all parameters (age, material and usage) are significant, although some groups are harder to compare due to the low number of assets.

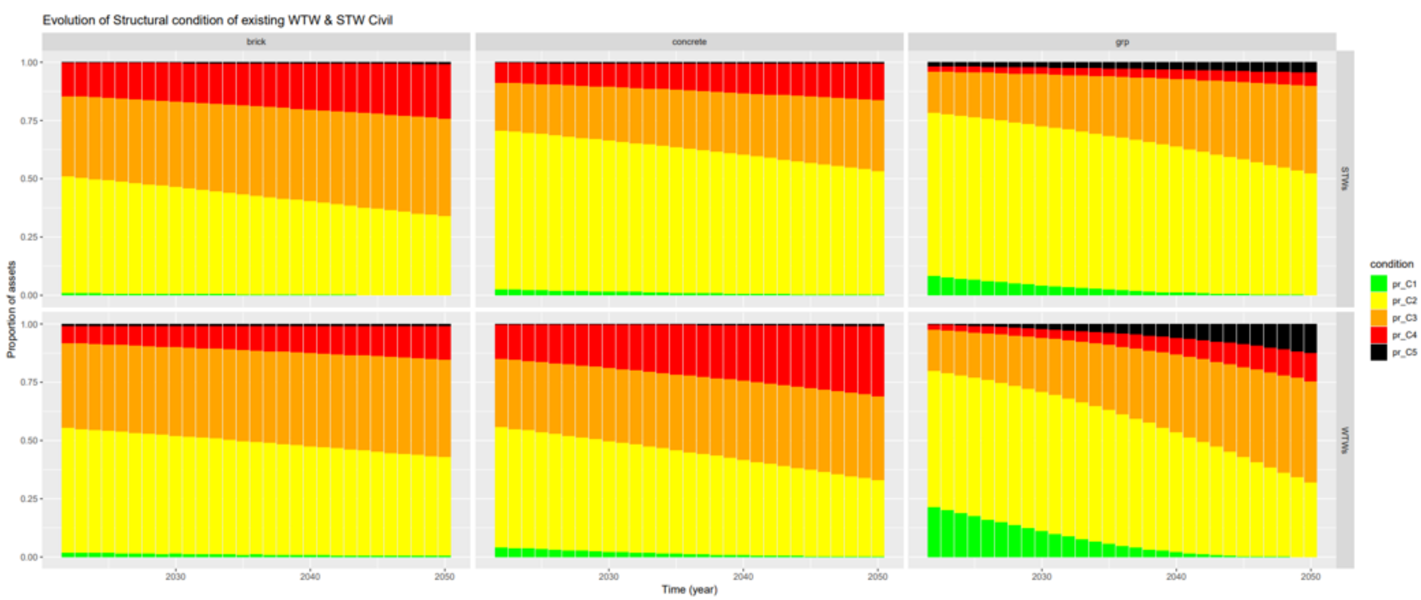
4.2.5 Forecasting asset deterioration and condition

We used the validated model to forecast changes in asset condition over time, including:

- Predicting the deterioration of individual and groups of assets.
- Quantifying the number of assets reaching condition grade 4 up to 2050.
- Apportioning defect location between condition grades 3 and 4.

We used the validated statistical model to generate the information in the following graphs (from Figure 25 onwards) which forecast deterioration in the condition of WWTW (brick, concrete and GRP) and WTW (brick, concrete and GRP) between 2022 and 2050.

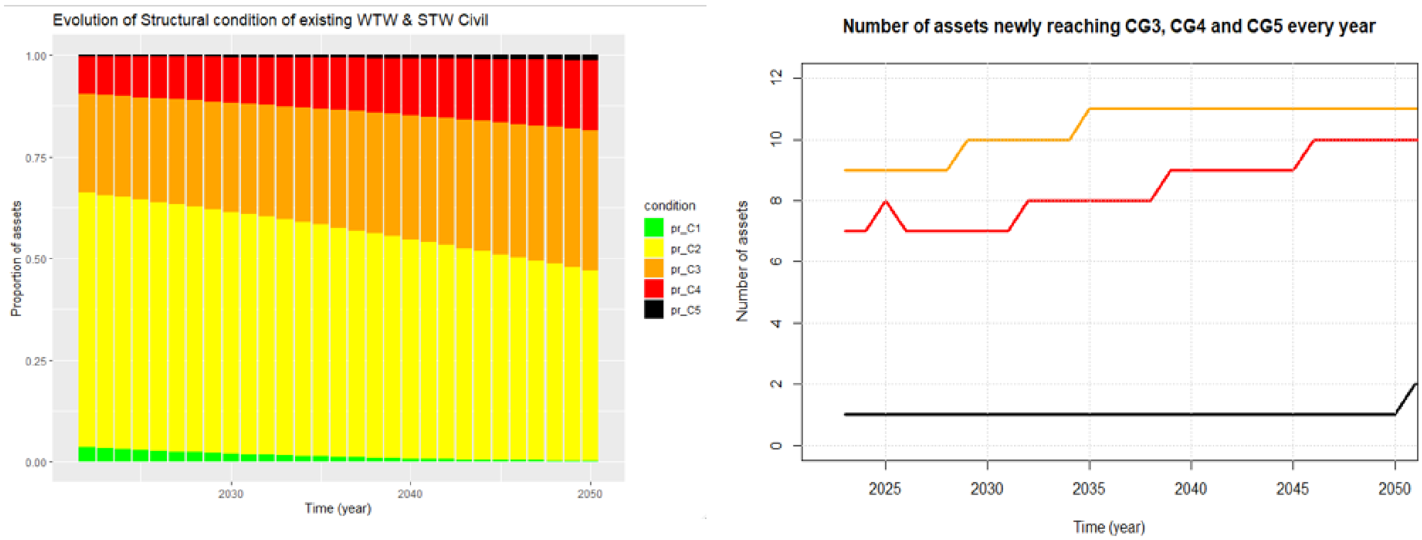
FIGURE 25: FORECAST DETERIORATION OF CIVILS TANKS BY USAGE AND MATERIAL



This shows a movement of civils structures through the condition grades towards grades 3, 4 and 5, as we would expect. The rate of change varies according to usage (WWTW or WTW) and material with a noticeable movement towards grades 4 and 5 for GRP tanks (which is to be expected because GRP tanks have a lower design life).

We also used the model to generate the information below which forecasts the number of civils tanks moving from condition grades 2, 3 and 4 into grades 3, 4 and 5 between 2022 and 2050. This analysis is for WTW and WWTW combined and all materials.

FIGURE 26: FORECAST DETERIORATION OF CIVILS TANKS



The results show that every year for the next six years there will typically be:

- One asset reaching condition grade 5.
- Seven assets reaching grade 4.
- Nine assets reaching grade 3.

We expect that the result of only one asset reaching condition grade 5 in each year is a limitation of the dataset. This is because condition grade 5 assets are removed as they are replaced or remediated to a better condition. In light of this “survivor bias”, we can assume the rate of deterioration into condition grade 5 would be higher (in line with the 9 or 7 for condition grade 3 or 4) if we could adjust for the effects from our maintenance of these assets.

4.2.6 Summary

Our analysis provided shows that many of our long-life assets are ageing and will continue to deteriorate during the PR24 period, at increasing risk to customer service and the environment. This is despite fully spending our capital maintenance allowances and targeting high risk assets during the last 20 years. Increased levels of expenditure are required to maintain the health of long-life assets to meet environmental standards and customer expectations.

Annex 4 provides a list of all the WTW and WWTW with civil structures in condition grade 4 and 5, plus a summary of the key issues for each of the works.

4.3. WATER MAINS

4.3.1 Historical mains renewal rates

During discussions about asset health and forward-looking approach to funding with the sector[33], Ofwat presented data showing a decreasing rate of mains renewal activity. We show this data in Figure (in section 3.1.2, above). Alongside this data, Ofwat noted that according to burst rates, there is no evidence suggesting asset health is worsening.

There are two main exogenous reasons for the decline in renewal rates:

- Historical quality programme funding for DWI S19 undertakings requiring many companies to replace additional mains prior to 2010 to reduce discolouration and the potential for iron failures pushing up the rates of replacement at the start of the period within Ofwat's chart (Figure).
- In recent years, regulatory incentives around reducing leakage have driven a focus on asset health investment in different activities, reducing the rates of replacement at the end of the period within Ofwat's chart (Figure).

Neither of these effects are immediate. It is possible that the decline in burst rate seen over the 20-year period of Ofwat's data is partly due to the high mains renewal at the start of the 20-year period driven by water quality concerns. Burst rates are also affected by other operational and maintenance activities, such as pressure management and calm networks, which tend to mitigate against poor condition rather than to improve condition and over time problems will resurface.

4.3.2 S19 undertakings

Ofwat's draft and final determinations from PR04 show that, in addition to efficient capital maintenance allowances, companies were allowed a total of £806m (2002/03 prices) to reline 6,436 km and replace 6,988 km of distribution mains as required by S19 undertakings during 2005-2010[34]. This was the continuation of a programme of DWI-driven improvements which was started soon after privatisation and completed by 2010. Such a programme increased the level of mains renewal to catch up with pre-privatisation lack of investment and make a step change in water quality.

4.3.3 PR19 leakage reduction focus

Since the PR19 final determination we have responded to the regulatory incentives to make a step change in leakage through targeting specific cost-effective activities such as find and fix repairs, installing equipment and undertaking training to enable us to operate a calmer network, increasing the scale of logging in our Essex and Suffolk networks and a

[33] Ofwat, September 2021, cost assessment working group – Forward looking capital maintenance, slide 12.
[34] Ofwat, December 2024, PR04 final determinations, p.`197 table 34. The draft determination. The draft determinations showed an assumption of 7,008km of replacement at an allowance of £410m (2002/03 prices)

programme of pressure management including installing pressure reducing valves. We forecast we will overspend on capital maintenance during AMP7 and we are spending now in line with that expectation. This has resulted in a decrease in overall mains renewals.

However, there is a limit to the pressure reduction measures we can take, and without a return to focus on mains renewal we forecast stagnation of leakage reduction and increasing numbers of bursts over the long-term.

At PR19, some companies that were forecasting upper quartile performance in leakage, for example SES Water, were allowed enhancement funding for additional mains renewal activity to deliver leakage improvement programmes. In allowing this enhancement funding, Ofwat recognised that as the sector brings leakage down there will be an increased level of mains renewal to drive further performance improvements.

Likewise, we propose to reduce leakage in Essex and Suffolk during AMP8 through an additional targeted programme of mains renewal (see our water demand enhancement case, NES15). For the North Suffolk water resource zone, we will have exhausted opportunities to drive further leakage reductions from additional pressure management, logging and calm networks interventions during 2025-30 (that is, we will have reached the UARL, as explained in NES15. This is a more expensive intervention, but this necessary due to the low levels of leakage in this water resource zone (and Essex and Suffolk as a whole) compared to the rest of the industry, and the supply/demand deficit identified within this region. From 2040, we expect that long-term leakage reductions will require an increase in mains replacement in all of our water resource zones in the North East and Essex and Suffolk regions.

Section 4.4 below sets out the evidence that an increase in mains replacement rates is appropriate, including international practice, and the latest understanding of the economic and engineering lives of water mains.

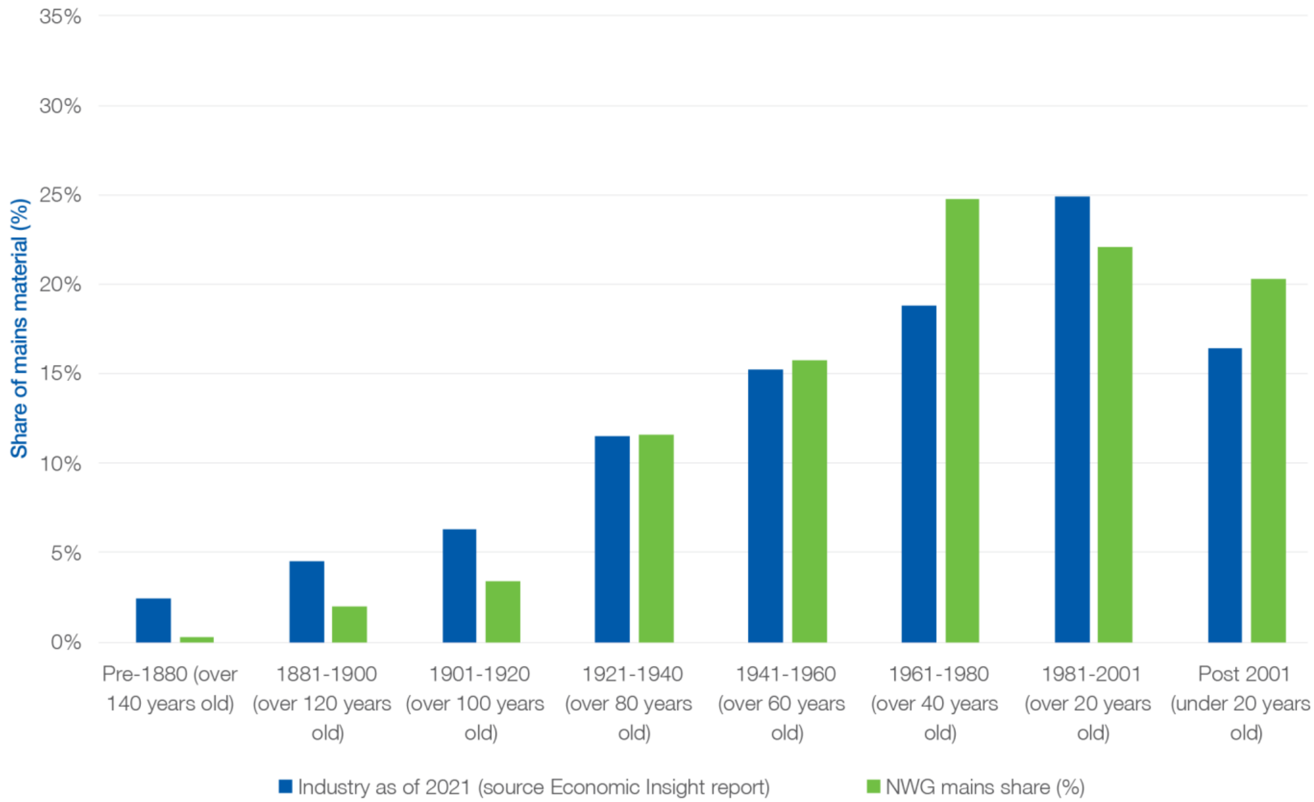
4.4. THE AGE AND MATERIALS OF OUR MAINS

Our network is not as old as that of some companies, as illustrated in Figure 27. This is in part because we had a large water quality enhancement S19 programme in the north during the 1990s and 2000s which saw us renew high proportions of our cast iron (CI) pipes. They were causing risks to water quality iron failures and discoloured water due to the interaction of the pipe material with aggressive upland waters.

Pipe lining was a significant aspect to the S19 programme, since the CI pipes themselves were found to have a useful remaining asset life. However, those CI pipes are now reaching the end of their useful lives, which was anticipated to be likely to occur 30 years on from the start of the S19 programme. Bursts are happening with increasing frequency on lined CI pipes. We expect the burst rate of lined CI pipes to continue to increase based on our understanding of how CI behaves in our area.

Most mains we lay now are polyethylene (PE) which has been found to be a stable material and is currently meeting expectations of a long asset life, as described in section 4.5.3.

FIGURE 275: OUR MAINS AGE COHORTS COMPARED TO INDUSTRY AVERAGE, SHARE OF MAINS (%)



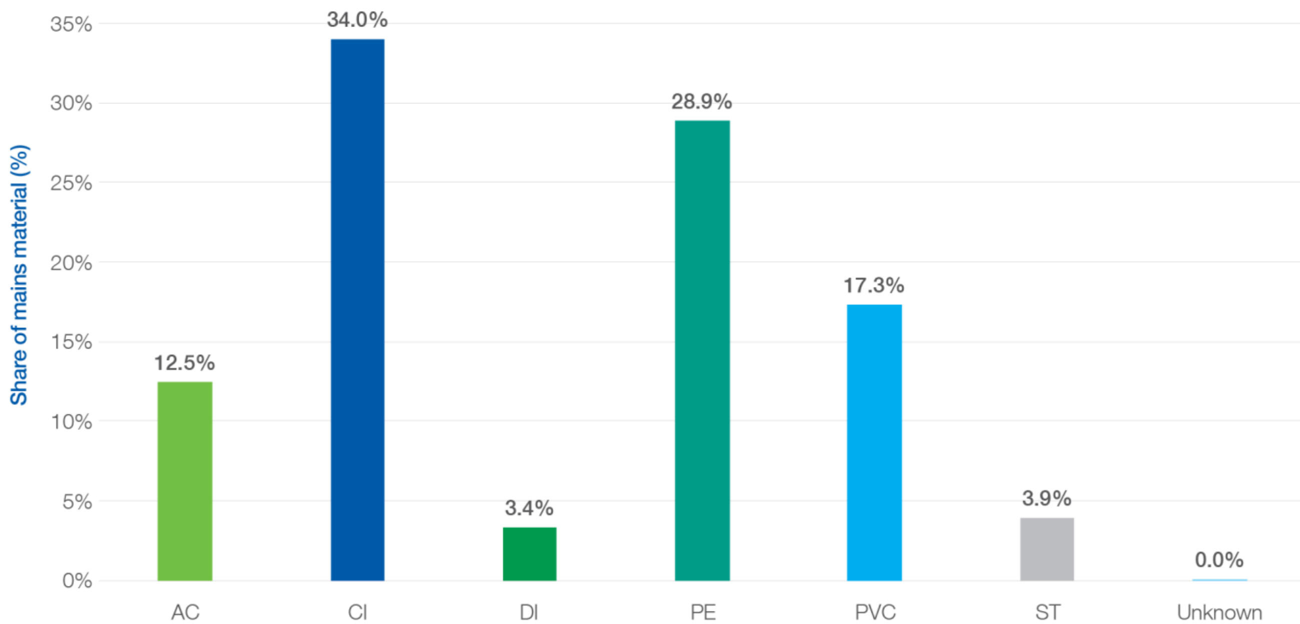
Source: NWL asset intelligence data

In addition, in aggressive or clay soils, which can be found in all our regions, CI represents the most significant burst risk. Climate change modelling tells us this risk is increasing the likelihood of dry summers which put further pressure on mains laid in the soils in our areas. Figure 28 shows how, despite the large mains replacement programme undertaken in the 1990s and 2000s, CI is still the most common material in our network by length, emphasising the significance of the risk that deterioration in CI represents to our mains performance.

The climate change-related increasing risk of dry summers as well as freeze-thaw response particularly impacts Asbestos Cement (AC). Due to its interaction with the water and soil in the north most AC pipes there have been replaced, but their deterioration is much slower in the south. We therefore have higher proportions of AC pipes in Essex and Suffolk than in the north. However, this leads to a significant climate change risk from these pipes in our southern regions.

We are also aware that some other companies have seen customers complain about the use of AC mains in their communities. There is no evidence linking AC pipes to public health risk for consumers. However, some companies have long-standing campaigns from groups enquiring about a renewal strategy for AC.

FIGURE 28: PIPE MATERIALS IN OUR MAINS



Source: NWL asset intelligence

Our PVC mains represent the next most significant overall burst risk to CI at the company level. Many of the mains laid between 1961 and 1980 are PVC, with it being considered the best modern material at the time. PVC has been found to age quickly, becoming brittle which leads to increasing burst rates. It therefore has a shorter asset life than CI or PE. Significant proportions of our northern and Suffolk pipes are PVC, but not such a high proportion in Essex.

The range of pipe materials and age cohorts of them illustrate the complexity around understanding an efficient level of renewals. Each material and age band needs separate assessment and optimisation against the suite of performance metrics to get to an optimised programme of mains renewal which will be different for each company and vary over time.

4.4.1 Timing of investment

Since the completion of the extensive AMP3/AMP4 S19 quality mains renewal programme, our overall expenditure on mains renewal has been relatively stable, as shown in Figure 10. This clearly demonstrates that our level of reactive spend is increasing at a higher rate than our overall level of mains expenditure, and if the upward trend in reactive spend continues, it will surpass the trend in our overall level of investment in mains renewal within AMP8. This helps to illustrate the immediacy of the problem we face and the need to increase investment in AMP8.

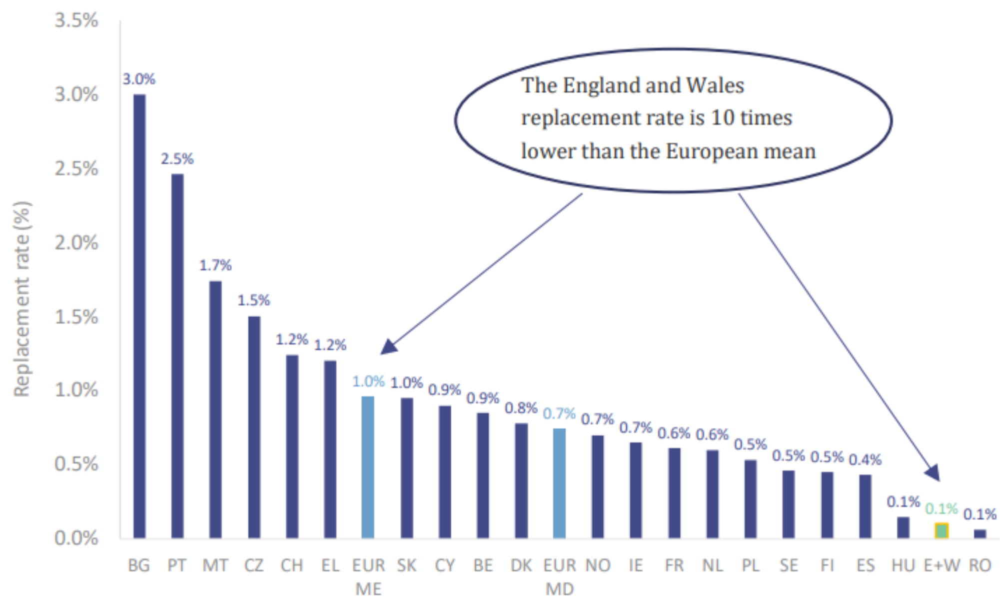
This increasing expenditure on reactive renewal follows our expectations with respect to increasing burst rates as certain cohorts of our pipes reach the age when we expect bursts to increase.

4.5. INFORMING THE LONG-TERM EFFICIENT MAINS RENEWAL RATE

4.5.1 International practice

In England and Wales, we are replacing mains at a lower rate than almost all European countries, and well below the European mean (see Figure 29 taken from the Economic Insight report provided for Water UK). This would be the case even for Ofwat's assumption at PR19 that companies could renew 0.4% of mains per year.

FIGURE 29: MAINS REPLACEMENT RATES IN EUROPE



Sources: Economic Insight analysis of the following data sources: (i) 'Europe's Water in Figures.' EurEau (2021); and (ii) 2021 Annual Performance Reports.
Notes: The renewal rate of water assets for England and Wales is calculated as the 'Total length of potable mains renewed' in 2020-21 divided by the 'Total length of potable mains' at the start of the 2020-21 reporting year. European data relates to average asset renewal rate for drinking water infrastructure for periods 2017-2019 (depending on the country), while the data for England and Wales relates to 2021.

Figure 29 shows data from 2021 for England and Wales. Even if we look over a longer period, we still see rates well below the European average. For example, over the last 5 years (2018/19 to 2022/23) we observe mains replacement rates of 0.17% which is still less than a fifth of the rates seen elsewhere in Europe, and still imply an implausibly high implied asset life of almost 590 years. Although not conclusive, this evidence points to different practices elsewhere in Europe.

International academic papers demonstrate a range of replacement rates. For example, a tool was developed for an EU project to support forecasting mains renewal rates.[35] Swedish authors have published their application of the tool.[36] They show that the annual renewal rate for Swedish water pipelines should be >0.7% and for distribution pipes and >0.6% of the total length (including larger trunk mains).

4.5.2 Consideration of mains asset health elsewhere in the UK

As part of the Strategic Review of Charges 2021-2027, Scottish Water and WICS considered the asset replacement requirements over the short and medium term and on an ongoing basis. As part of this work, they examined the lives of the different assets and the implied annual replacement expenditure implied by these estimates. This estimated lifetimes of 90-140 years for water mains >300mm and 80-130 years for water mains < 300mm.[37]

This analysis was used to show that historical rates of expenditure were too low and that around an 80-123% increase was required in the long term.

4.5.3 Current understanding of technical life of water mains- manufacturers asset life

The current material which we typically use when replacing distribution mains is polyethylene (PE). Manufacturers estimate an asset life of 100 years, and current industry understanding is that the asset life of PE pipes is expected to match manufacturer’s expectations. However, this is not guaranteed since no PE pipe is yet approaching 100 years of operational service.

Even assuming manufacturers have made a conservative estimate of the asset life of PE pipes, using a long-term renewal rate implying a forward looking 250-year asset life is likely to be pushing today’s asset replacement costs on to future customers. Just as there is no evidence of PE pipes deteriorating beyond their economic useful life before their 100-year asset life, neither is there evidence that confirms it is appropriate to use an asset life more than double the manufacturer’s understanding of the materials they are supplying.

4.5.4 Current understanding of technical life of water mains- deterioration testing

The UK started using polyethylene (PE) potable water mains as the material of choice for both new mains and pipe renewals in the 1980s. We adopted this approach and we fit almost exclusively high-density polyethylene (HDPE) for distribution mains and ductile iron for larger mains. Being a new material in the 1980s and following emerging problems then with PVC pipes bursting due to brittle failure, a conservative estimate of minimum design life for PE was 50 years.

[35] Sægrov S. (2005). Care-W Computer Aided Rehabilitation of Water Networks, 1843390914. IWA
[36] Malm A. & Svensson G. (2011). Material and age Distribution for Sweden's WW Network and Future Renewal Needs, SVU Rapport, 13.
[37] Asset Replacement.pdf (wics.scot), page 21

To aid understanding of deterioration processes and operational asset life, in the 1980s and 1990s a test was undertaken where two polyethylene pipe test beds were buried that were fully analysed chemically and mechanically before installation. A 2020 UKWIR funded collaborative project has exhumed several of these pipes and repeated these tests.

Analysis on these pipes showed that some of the newest HDPE pipes could last as long as 160 years.[38]

This research confirms we are using appropriate materials now for our mains renewal programme that are forecast to have a long asset life, but also indicates some relatively modern materials such as medium density PE may have considerably shorter asset life before brittle failures start to occur.

4.5.5 Our approach to improve our understanding of the technical life of our mains

We are maturing our base asset health approach and undertaking asset health assessments (Figure 1 shows our progress against the AMMA framework). This will require that we calculate the ratio of conditional age (observed engineered life) divided by the projected economic life expectancy. The result of this work will be an assessment of remaining asset life based on observed condition for each of our assets we will then prioritise our intervention strategy based on the criticality of each individual asset. This is a significant piece of work, involving significant additional investment in our inspection programme, and we will continue to develop this during AMP8.

4.5.6 Pipe aging, materials and burst rates

We have a comprehensive understanding of our network and track the age of each main that bursts to inform us about the deterioration of the materials we have installed. This helps us target our proactive mains renewal programme.

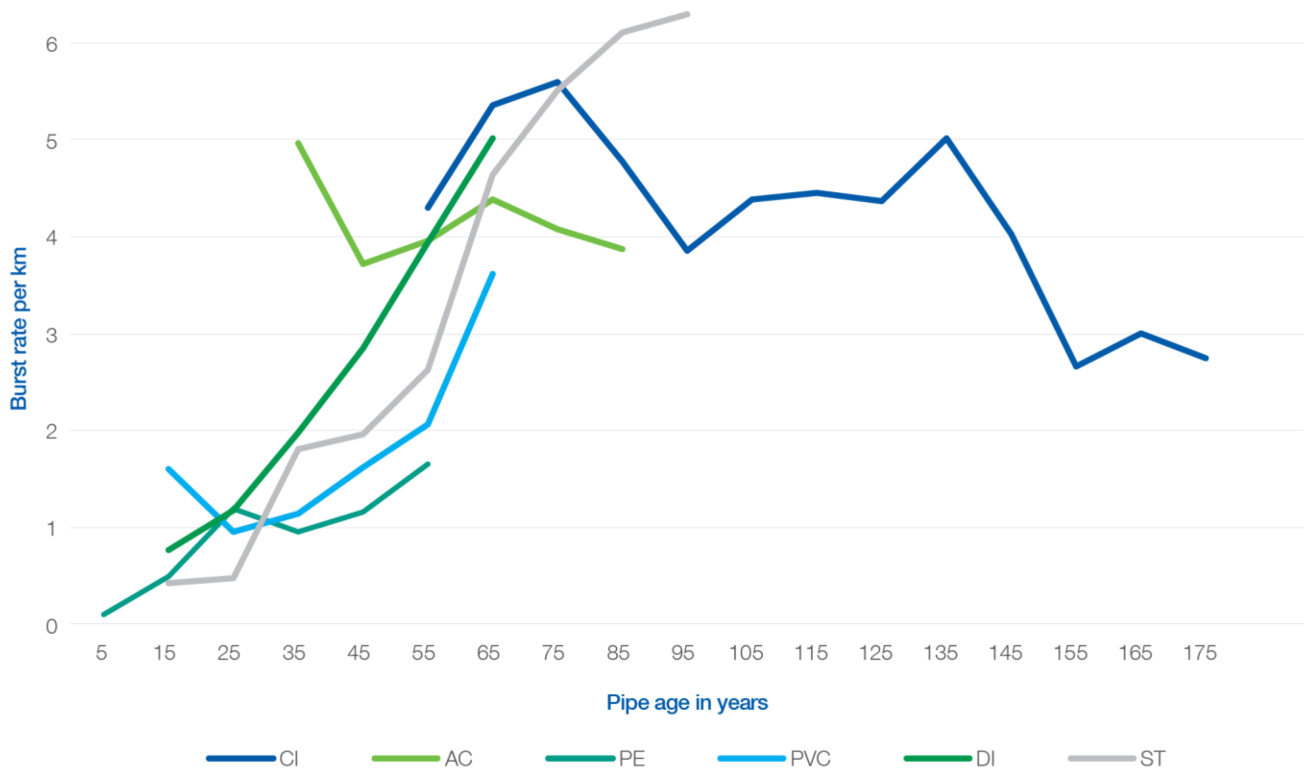
Figure 30 shows the materials of our complete water supply network which includes larger trunk mains and distribution mains. It shows there are increasing burst rates as materials age, but that some materials are seeing higher burst rates than others at the same age. It also indicates that our current material of choice for mains replacement and new mains, PE, is aging well. The rate of increase in bursts per km for PE is lower than the other materials. However, the chart also shows that as more of our pipes reach an age greater than 40 years, without a significant replacement programme we can expect burst rates to increase.

We note the relatively stable cohort of cast iron (CI) mains that are the oldest in our network that are included in this chart. These are typically the larger diameter trunk mains that had a different method of construction and which we discount from our distribution mains renewal programme. Instead, we undertake a targeted and strategic approach to trunk mains replacement.

[38] UKWIR, 2020 [Long-term aging of polyethylene pipes (ukwir.org)](ukwir.org)

We discuss the particular issues we face with the age, distribution mains pipe materials and geographical factors in our regions below.

FIGURE 30: WATER SUPPLY PIPELINE MATERIAL AND BURST RATE PER KM VS PIPE AGE IN YEARS



Notes: CI = cast iron; AC = asbestos cement; PE = polyethylene; PVC = polyvinyl chloride; DI – ductile iron; ST = steel

4.5.7 Current understanding of economic life of mains

In the past, we have calculated the remaining life of our assets based on “useful life”. We have defined the end of useful life as the point in time when any further failure or deterioration will have an unacceptable impact on:

- customer health;
- quality of service;
- the environment;
- compliance with regulatory and statutory requirements;
- health and safety;
- operational expenditure, or
- loss of income.

We summarise our most recently assessed view of the remaining economic life of our entire water supply pipe network in Figure 31, in which we assume a maximum economic life of 100 years for newly installed mains. As part of our current asset health strategy, we will further develop our inspection strategy during the rest of 2020-25 and then deliver this during 2025-30 to enhance our understanding of the criticality and condition of our pipes.

FIGURE 31: REMAINING ECONOMIC LIFE OF OUR WATER SUPPLY PIPE NETWORK (2021 ASSESSMENT)

Total length of water supply pipe network at 31 March 2021 (km)	**26,253**
Remaining economic life at 31 March 2021	**Length of network (km)**
less than 10 years	1,534
10-20 years	1,534
20-30 years	1,714
30-40 years	1,714
40-50 years	2,655
50-60 years	2,655
60-70 years	4,159
70-80 years	4,159
80-90 years	3,064
90-100 years	3,064
More than 100 years	0

Despite having a relatively younger asset base than many companies, 5.8% of our network is within 10 years of the end of its economic life and a further 5.8% within 20 years.

5. COMPARISON TO EXISTING ALLOWANCES

- Section 5.1 highlights how the issues driving the cost requirement here are not unique to NWL and are infact likely to be sector-wide.
- Customers must not pay twice for capital maintenance funding and section 5.2 explains our overall approach to calculating what is already funded in the base allowances that we expect Ofwat to set.
- Section 5.3 sets out the approach for water mains, which is based on calculating the levels of mains renewals observed over the period covered by the efficiency challenge in the base cost models and deducting that from the volume of mains renewal that wish to undertake through this enhancement funding.
- Section 5.4 sets out our approach and analysis for civil structures. Calculating the implicit allowance for maintenance and replacement of civil structures is more challenging because consistent and comparative sector-wide data is not available so we have examined our own historical data to estimate the level that can be funded from base allowances via analysis of the Fixed Asset Register and a project level review of our costs.
- Section 5.5 provides simple analysis demonstrating that the value of these costs are material.

a) Is it clear how the company has arrived at its option costs?

b) Is there supporting evidence on the calculations and key assumptions used and why these are appropriate?

c) 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 from base cost models?

g) Is there compelling evidence that the cost claim is not included in our modelled baseline or that the factor is not covered by one or more cost drivers in the cost models?

h) Is the claim material after deduction of an implicit allowance? Has the company considered a range of estimates for the implicit allowance?

i) Has the company accounted for cost savings and/or benefits from offsetting circumstances where relevant?

j) Is it clear the cost allowances would in the round be insufficient to accommodate the factor without a claim?

k) If an alternative explanatory variable is used to calculate the cost adjustment, why is it superior to the explanatory variables in our cost models?

Capital maintenance expenditure is funded from within base allowances. In this section we explain what level of funding we consider is provided for within those allowances and the investment that this could support in the 2025-30 period to ensure that customers no not pay twice for these investments.

5.1. OUR CIRCUMSTANCES ARE NOT UNIQUE

We decide how to invest the capital maintenance allowances that we have funding for from our base allowances, this is entirely within our control and we highlight in section 3.5 how our asset management performance has recently been identified as sitting between ‘competent’ and ‘optimising’ according to Ofwat’s AMMA framework. However, whilst the maintenance of these assets is entirely within management control, the investment required is not fully accounted for in modelled allowances and is material. This analysis is provided below separately for civil structures and mains renewal.

5.2. APPROACH TO ASSESSING WHAT IS ALREADY FUNDED IN BASE ALLOWANCES

In each case we seek to initially understand what level of activity will be funded from the base allowances and then compare that to the costs of the preferred options set out in section 4, which have been benchmarked (as we explain in section 7) to ensure that they are efficient. For the PR24 business plan we then propose funding for the difference between these two figures ensuring that customers do not pay twice for this investment.

In estimating the level of activity that can be funded from base allowances we need to consider the approach that Ofwat’s uses to set base cost allowances and in particular identify the efficient level of activity that is likely to be funded from that process. We focus on the period over which we understand Ofwat will assess cost efficiency, namely 2018/19 – 2022/23, covering the last 5 years. So for both civil structures and mains renewal we look at activity levels over this period primarily.

We then need to consider what level of activity would be funded from the modelled allowances. Here different approaches are likely to be most effective for civil assets and water mains depending on the level of public and consistent disaggregated reporting information across the sector of both expenditure and activity levels. Companies report disaggregated data for levels of mains renewal each year, so we use this data to infer what the ‘efficient’ level of mains renewal is that is funded from the modelled cost allowances. We also examine the level of mains renewal that the companies setting the efficiency benchmark have undertaken, to do so we use all the proposed PR24 models in aggregate as we cannot be sure which models will be used ultimately.

For civil structures on treatment works there is not separate and consistent reporting of either levels of expenditure and activity across companies’ so we use our own historical cost and activity reporting information to identify what has been spent on these assets previously to be able to deduct these values from our base allowances.

5.3. WATER MAINS RENEWAL RATES

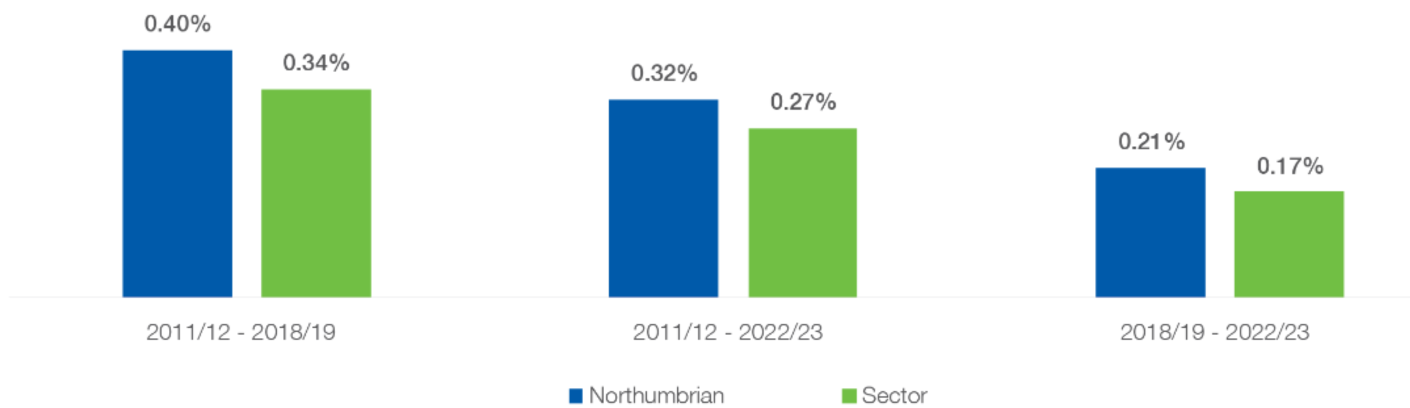
5.3.1 Implicit allowance in base cost models

Ofwat sets allowed costs including to maintain asset resilience mainly through base expenditure. In its PR24 Final Methodology, Ofwat state that water companies were funded at PR19 to renew their water mains at an average rate of 0.4% per year. It believes that ‘*historical base allowances have been sufficient for companies to maintain and improve outcomes and asset health metrics over previous periods and be resilient to climate change impacts*.’

We agree that the limited lagging asset health metrics that we observe and target across the sector have generally improved and not deteriorated but we do not believe the level of totex allowance has been adequate to undertake the 0.4% levels of mains replacements across the sector. Figure 32 shows the average renewal rates covering three different historic periods:

1. **The PR19 period,** 2011/12 – 2018/19. The average renewal rate obtained from this period covers the econometric modelling period used at PR19 by Ofwat.
2. **The full sample period,** 2011/12 – 2022/23. This period includes data that have been received since PR19. It is the likely data that would be used by Ofwat in the econometric modelling at PR24.
3. **The efficiency period**, 2018/19 – 2022/23. This period covers the last 5 years only. Consistent with Ofwat's PR19 methodology, we assume efficient allowances at PR24 would also be set based on this period.

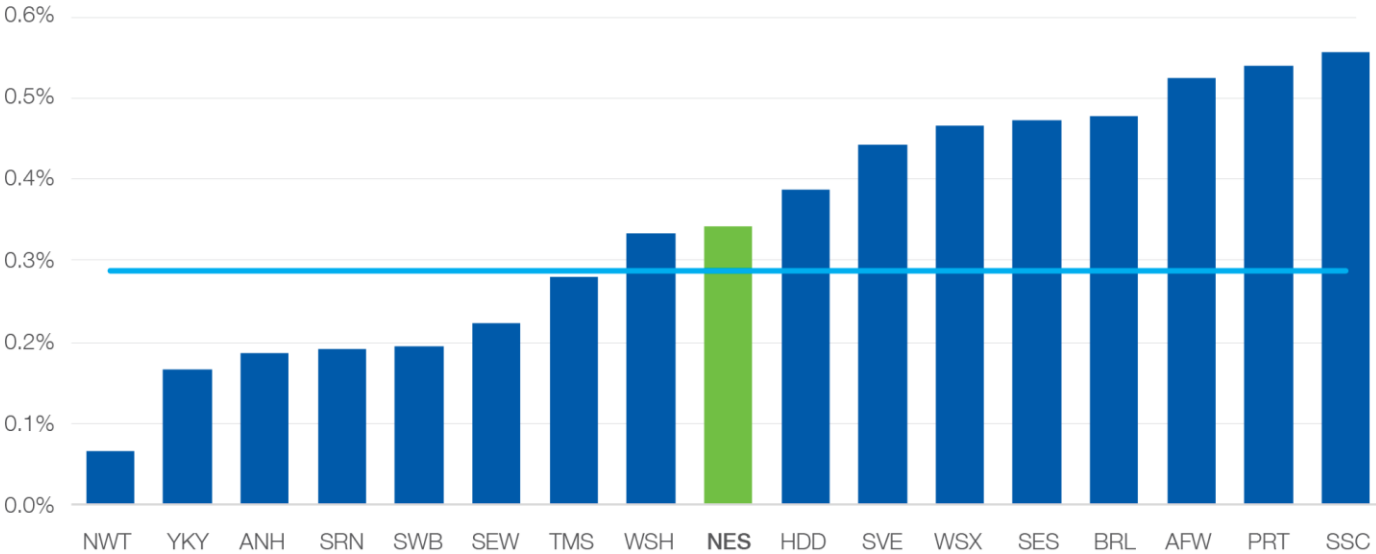
FIGURE 32: AVERAGE ANNUAL MAINS RENEWAL RATES



Source: Ofwat's April 2023 consultation and 2023 APRs

The sector-wide average levels of mains renewals over the three periods are significantly lower than 0.4%. This indicates that the implicit allowance companies obtain from the models to renew their mains are lower than what Ofwat assumes companies were funded for at PR19.

FIGURE 33 ANNUAL AVERAGE RENEWAL RATES OVER THE PERIOD, 2011/12 - 2021/22



Source: Ofwat's April 2023 consultation

Expenditure on Treated Water Distribution infrastructure – maintaining the long-term capability of the assets and the renewals expensed in the year was used to capture the costs associated with mains renewals.

Under Ofwat's totex approach, companies have the flexibility to choose how they invest their base allowance across their different activities in order to meet regulatory commitments and incentives. Ofwat state that '*We expect companies to manage cycles of maintenance across large, diverse asset bases within their long-term average cost allowance, and companies have a duty to maintain an efficient and economical system of water supply, including maintaining water mains.*[39]'

Across all three periods, our water mains have been consistently renewed at a rate higher than the sector. However, the average renewal rates that would be used at PR24 for the base modelling period have fallen by 20% when compared with the PR19 base modelling period. We do not believe the implied allowances from PR24 base modelling will be sufficient. We consider this level too low, unsustainable, and insufficient to maintain the asset health. This is ultimately not in the customer's long-term interest.

Ofwat assumes its base econometric models provide allowances for companies' mains renewals. However, there is no specific link between a level of mains renewal and the cost allowance. There are five cost drivers used in the Treated Water Distribution models proposed by Ofwat during the April 2023 base consultation:

1. Total length of potable mains;
2. Booster pumping stations per length of mains;
3. Average pumping head;

[39] PR24 final methodology Appendix 13 data and modelling.pdf (ofwat.gov.uk)

4. Weighted average density; and
5. Properties per length of mains.

None of these cost drivers explicitly captures the variations in companies' treated water distribution costs that is due to mains renewals activities. Ofwat believes including a cost driver that captures mains renewals could lead to perverse incentives[40] as it is under management control. We place the renewal rates of companies based on the last 5 years, alongside their efficiency performance scores in treated water distribution at both PR19 and PR24, shown in Figure 34. These efficiency scores essentially provide a ratio between a companies' actual and modelled costs.

FIGURE 34: EFFICIENCY SCORES FOR BASE MODELS AND COMPANY MAINS RENEWAL RATES

PR19 FD			April 2023 consultation		
Company	Score	Renewal rate	Company	Score	Renewal rate
PRT	0.80	0.44%	SWB	0.78	0.08%
SWB	0.81	0.08%	PRT	0.87	0.44%
SRN	0.82	0.06%	NWT	0.94	0.04%
NWT	0.90	0.04%	SRN	0.99	0.06%
WSX	0.92	0.26%	SVE	1.03	0.31%
SES	1.00	0.31%	NES	1.04	0.21%
SVT	1.03	0.31%	TMS	1.04	0.28%
YKY	1.03	0.07%	HDD	1.06	0.32%
TMS	1.04	0.28%	WSX	1.09	0.26%
DVW	1.06	0.32%	SEW	1.12	0.16%
NES	1.09	0.21%	SES	1.13	0.31%
WSH	1.09	0.13%	SSC	1.14	0.34%
AFW	1.17	0.15%	WSH	1.19	0.13%
SSC	1.18	0.34%	YKY	1.19	0.07%
BRL	1.22	0.24%	AFW	1.21	0.15%
SEW	1.25	0.16%	BRL	1.24	0.24%
ANH	1.25	0.12%	ANH	1.28	0.12%

Source: Ofwat's April 2023 consultation

With the exception of Portsmouth Water, the four companies setting the upper quartile benchmark in the treated water distribution model have comparably lower renewal rates. We acknowledge other factors may play a part but it is unlikely this relationship is completely coincidental.

Implicit allowance calculations

The implicit allowance captures the allowance due to mains renewals which is covered by Ofwat's modelled cost baselines. Ofwat's modelling approach does not specify any specific level of activity carried out by water companies that has been 'funded' in the past or will be funded in the future. Assumptions will therefore need to be made.

[40] Econometric_base_cost_models_for_PR24_final.pdf (ofwat.gov.uk)

Ofwat has previously presented three approaches to estimating the implicit allowances. As mains renewal costs are not directly captured in the modelling data, we focus on only the third approach – assessment of the average unit costs of mains renewals. This provides an objective way to estimate the implicit allowance set by the models. We consider the average amount of activity which the sector has delivered in this area within the time frame Ofwat considers when setting allowances, that is, the most recent five years.

We set out below our four steps to assessing the implicit allowance based on the average unit cost approach:

1. **Company and sector renewal rates.** The historic annual renewals rate for each company and the sector is calculated as:

$$Renewals\ rate = \frac{length\ of\ potable\ mains\ renewed + length\ of\ potable\ mains\ relined}{total\ length\ of\ potable\ mains}$$

2. **Sector average renewal rate**. This is the mains renewal rate implicitly funded by Ofwat's models. It is calculated as the average of the historic sector mains renewal rates over the efficiency period we set out earlier, that is, the most recent five years, 2018/19 – 2022/23.
3. **Northumbrian mains renewed.** This defines our implied length of mains renewed that is funded by Ofwat's base models. It is obtained by multiplying the implicit rate calculated above in Step 2 with the AMP8 forecasts of the length of our potable mains.
4. **Implicit allowance.** We obtain the implicit allowance by multiplying our implied length of mains renewed with the forecast of unit costs for mains renewal.

FIGURE 35: IMPLICIT ALLOWANCE (2022/23 PRICES)

	2025/26	2026/27	2027/28	2028/29	2029/30	AMP8
Forecast length of potable mains (km)	26925	27080	27163	27323	27463	135954
Sector average mains renewal rate (replacement rate implicitly funded by Ofwat's April 2023 base models) (%)	0.17	0.17	0.17	0.17	0.17	0.17
Forecast length of potable mains renewed (km)	45.77	46.04	46.18	46.45	46.69	**231.12**
Implicit allowance funded by Ofwat's April 2023 base models based on an efficient unit cost of £273.47/m	**12.52**	**12.59**	**12.63**	**12.70**	**12.77**	**63.20**

We have used a unit cost of £273.47/m in computing our implicit allowance. We believe this is an efficient cost for mains renewal based on rigorous internal and external benchmarking exercises carried out. Our cost efficiency approach is described in greater detail in the Cost efficiency section above. Our analysis suggests the implied allowance we would receive for mains renewals from Ofwat's base models is £63.20m over AMP8 period.

Gross allowance calculations

The Gross allowance is the estimated expenditure associated with our planned level of mains renewals over AMP8. We have set out a plan to renew 0.37% (503km) of our water mains at an efficient unit cost of £273.47/m over AMP8 period.

We would replace 0.17% of our water mains from our base allowance, consistent with the funding implied by Ofwat's econometric models. To further reduce leakage in our Suffolk operating area, we would replace 0.03% of our mains in this area as set out in our Water Resource Management Plan. This is not included in these calculations. On top of these levels, we commit to replace an additional 0.2% of water mains across our network.

Maintaining the current mains renewal across the sector is not sustainable. There has to be a shift to maintain asset health and prevent higher replacement costs in future AMPs. An increase in the current renewal rates is in the best interest of the customers in the long term. We believe our mains replacement program which results in a gross allowance of £137.56m in AMP8 is a step in the right direction. We provide the annual breakdown in the table below.

FIGURE 36 GROSS ALLOWANCE

	2025/26	2026/27	2027/28	2028/29	2029/30	AMP8
Forecast length of potable mains (km)	26925	27080	27163	27323	27463	135954
Forecast renewal rates **(%)**	0.37%	0.37%	0.37%	0.37%	0.37%	0.37%
Forecast length of mains renewed (km)	99.62	100.20	100.50	101.10	101.61	503.03
Gross allowance based on our forecast length of mains renewed at an efficient unit cost of £273.47/m (£m)	**27.24**	**27.40**	**27.48**	**27.65**	**27.79**	**137.56**

Net allowance calculations

The Net allowance due from our mains replacement program is estimated as the Gross allowance less the implicit allowance. This results in a total of £74.36m over AMP8. We break this down yearly in the table below.

FIGURE 37 NET ALLOWANCE

	2025/26	2026/27	2027/28	2028/29	2029/30	AMP8
Gross allowance (£m)	27.24	27.40	27.48	27.65	27.79	
Implicit allowance (£m)	12.52	12.59	12.63	12.70	12.77	
Net Allowance (£m)	**14.73**	**14.81**	**14.86**	**14.94**	**15.02**	**74.36**

5.4. CIVIL STRUCTURES

The level of maintenance activity allowed at previous Price Reviews and publicly reported by the industry does not provide sufficient detail to allow an understanding of the level of maintenance expenditure to offset material deterioration in civil asset structures at water and wastewater treatment works. Expenditure is reported in broad categories such as “maintaining assets – non-infrastructure” which, in addition to the expenditure considered in this case, will also include:

- Expenditure at other sites, such as network pumping stations.
- Expenditure in other asset types, such as electrical and mechanical.
- Expenditure on non-process civils such a fences.
- Proportional allocations to maintenance where investment with other drivers (e.g. new quality standards) creates an incidental maintenance benefit.

The complexity of how expenditure is classified and recorded in a myriad of approaches across the industry means that we are unlikely to be able to collect robust, accurate, granular and comparable industry data even with the support of other companies. Enabling this kind of data collection would require new guidance to standardise reporting and a decent time period from which to draw out trends.

In lieu of perfect industry data we instead use our own history as a proxy. This approach offers the advantage that given that expenditure allowances set through econometric models will reflect in part the history of the industry and the closest benchmark for our future expenditures is our own history. We also note that in aggregate our cost efficiency places us within the sector upper quartile when Ofwat’s cost models for PR24 are used in aggregate (across each of the price control elements).

This analysis of our historic costs comprises of two primary processes:

1. Analysis of the company Fixed Asset Register (FAR) to identify long-term historic levels of expenditure.
2. A project level review of recent history to identify directly comparable expenditure to establish a baseline for an implicit allowance.

FIGURE 38: HISTORIC PROCESS CIVIL EXPENDITURE AT WTWS WITH FORECAST AGE BASED REPLACEMENT

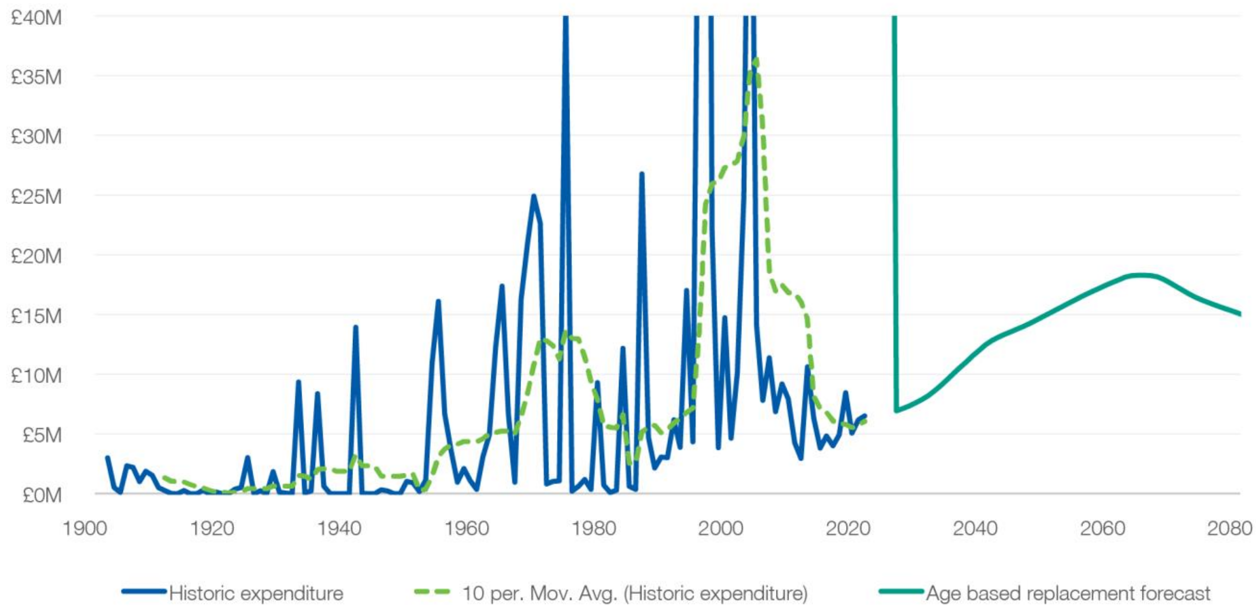
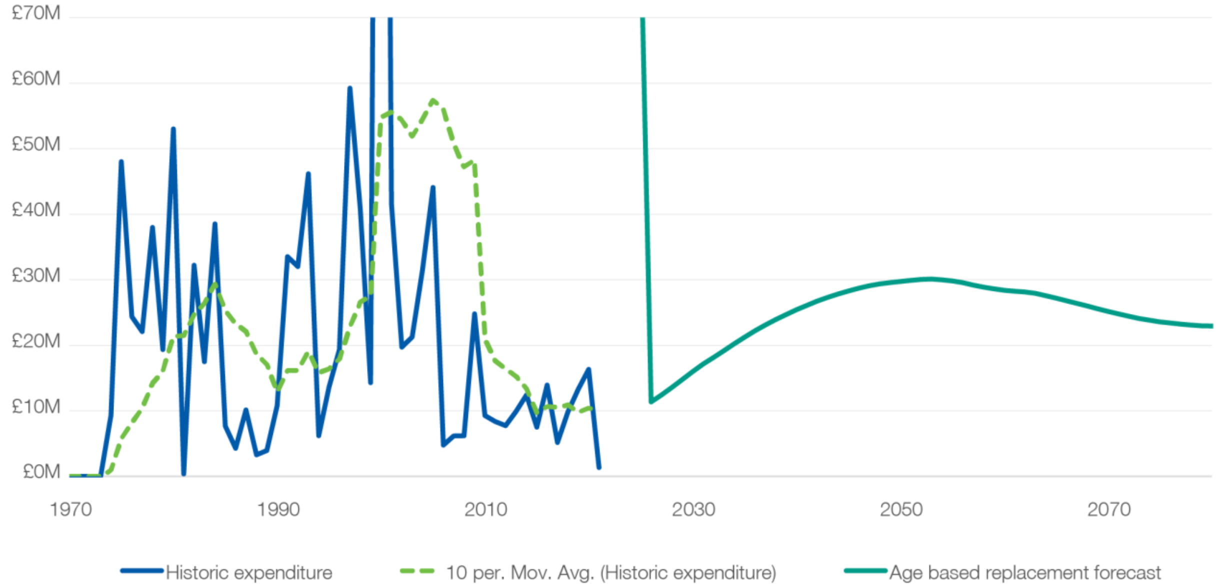


FIGURE 39: HISTORIC PROCESS CIVIL EXPENDITURE AT WTWS WITH FORECAST AGE BASED REPLACEMENT



The FAR analysis does show a historical record of expenditure on the base civil process assets at water and sewage treatment works. However, this is not exactly comparable to the scope included in this case which is proactive condition driven process civils maintenance. The FAR analysis will also include:

- Proportional allocation to base of enhancement projects.
- Enabling civils for mechanical, electrical and instrumentation maintenance, e.g. a new kiosk for replacement SCADA.
- Minor reactive civils maintenance.
- Below ground civils maintenance (e.g. pipework between treatment stages) which could not have been identified by the method of the Atkins surveys.

Using a seven-year period from the start of AMP6 the FAR analysis shows:

- For the water service – £39.9m of expenditure in the 7-year period from the start of AMP6 to 2021. Which would equate to a 5-year whole AMP comparator of £28.5m.
- For the wastewater service – £75.3m of expenditure in the 7-year period from the start of AMP6 to 2021. Which would equate to a 5-year whole AMP comparator of £53.8m.

To reach an estimate of historical expenditure which is more comparable to the scope of works proposed by this case a project level review was performed by our Tactical Planning Team. This review used information from the FAR analysis; principally the category 3 and category 4 asset descriptions at an individual journal line level, along with capital project outturn information in Project Accounting[41]. The Tactical Planning Team also sought assurance of the review from the Head of Water Supply North and the project sponsor for one of the largest minor works programmes. Independent assurance is underway on this project-level review.

The review sought to check five key factors and confirm that each was met in order to be included in the output:

1. Was the expenditure at a Water Treatment Works / Sewage Treatment Works site? The accuracy of site coding in the FAR is good and only 1.1% of expenditure for water and 0.4% for wastewater was excluded by this test.
2. Was the expenditure related to a civil asset? The accuracy of asset data and the data infilling exercise in the FAR analysis is relatively accurate and a further 2.5% of expenditure for water and 2.0% for wastewater was excluded by this test.
3. Was the civil asset for which investment was spent part of the treatment process? The Atkins survey did not seek to assess the condition of site fencing, staff welfare buildings, offices or other non-process civil assets. The infill in the FAR analysis to identify this proved to be quite accurate and a further 2.1% of expenditure for water and 11.7% for wastewater[42] was excluded by this test.
4. Was the civils asset for which investment was spent above ground? The scope of the Atkins survey did not include buried pipework on site which could not have been assessed with the survey method employed. There was no attempt in the FAR analysis to separate these, but the review revealed a comparatively small volume of expenditure on below ground civil assets at WTWs or STWs. A further 4.0% of expenditure for water and 1.6% for wastewater in the FAR analysis was excluded by this test.
5. Was the investment driver for poor condition of civil structures? There was no attempt in the FAR analysis to identify investment driver. A further 54.4% of expenditure for water and 63.9% for wastewater in the FAR analysis was excluded by this test.

The result of the review for water was that £11.4m over the seven-year period from the start of AMP6 was shown to meet these tests either by an in-depth review of the project details or by a light tough review which was applied to low value projects totalling 14.6% of the total value of work reviewed. The result of the review for wastewater was that projects totalling £39.6m over the seven-year period from the start of AMP6 was shown to have some expenditure which meet these tests. A conservative estimate of the expenditure within these projects showed £17.9m of expenditure would meet these tests[43].

The result of this review now includes only historic expenditure which is directly comparable to the scope of work proposed in this case. However, they are not directly equivalent as the historic expenditure also includes minor civil works which will continue in AMP8 alongside the proactive programme of work proposed in this case. The volume of minor civil works may

[41] Project ID was referenced using the asset ID in the FAR to allow an accurate mapping to be completed.

[42] 11.7% would be 4.2% with the exception of the civils work required to support the Bran Sands Gas to Grid project.
[43] The range on the analysis of expenditure within the identified projects was £14.1m to 17.9m.

be reduced from historic levels as proactive expenditure may offset some issue that might otherwise have emerged in AMP8. Considering this we are forecasting ongoing minor reactive process civils works of £1.7m at WTW and £4.6m at STW in AMP8. The implicit allowance we are estimating for this case therefore is £6.4m for water and £8.2m for wastewater, which is historic expenditure less the AMP8 ongoing minor works programme.

FIGURE 406: ANALYSIS OF CIVIL STRUCTURES IMPLICIT ALLOWANCES

	Water	Wastewater
FAR analysis (2015-2021)	£39.9m	£75.3m
FAR implied implicit allowance	£28.5m	£53.8m
Project level review	£11.4m	£17.9m
Resulting implicit allowance for AMP8	**£8.1m**	**£12.8m**
Proactive maintenance programme (i.e. Monte Carlo output for the case)	£24.2m	£102.6m
Ongoing minor maintenance‡	£1.7m	£4.6m
TOTAL AMP8 spend	**£25.9m**	**£107.2m**
Additional allowance	**£17.8m**	**£94.4m**

Source: Analysis of NWLs Fixed Asset Register and Project level review of capital programme data

5.5. MATERIALITY

Ofwat has set a materiality threshold for claims outside the allowance obtained from base modelling. The threshold for PR24 remains at 1% for water network plus and at 1% for wastewater network plus, similar to PR19[44]. The materiality threshold is calculated as:

$$Materiality = \frac{gross\ value\ of\ the\ claim - implicit\ allowance\ estimate}{totex\ for\ the\ control\ in\ 2025 - 30}$$

We are still finalising our business plan and therefore out totex numbers are provisional, but we do not expect them to change significantly to alter the materiality assessment presented below. The table below presents a provisional assessment of materiality for the items covered by this case.

FIGURE 417: PROVISIONAL MATERIALITY ASSESSMENT

Item	Provisional materiality assessment
Water mains renewal	4.1% of WN+ totex
Water civil structures	1.1% of WN+ totex
Wastewater civil structures	3.5% of WWN+ totex

Each item therefore meets the materiality thresholds that Ofwat has set out.

[44] PR24_final_methodology_Appendix_9_Setting_Expenditure_Allowances.pdf (ofwat.gov.uk)

6. BEST OPTION FOR CUSTOMERS

- We describe our process for considering options and selecting the best value option for customers on civil structures in 6.1 and 6.2, including the costs and benefits of delivering these in 2025-30 rather than delaying. Our analysis demonstrates that if we do not take action now then it will cost customers more in the future to fix these assets and consequence analysis confirms that the impacts from asset failure may be severe.
- We describe our process for selecting the right mains renewal rate in 6.3, and the right options for mains renewal in 6.4 and 6.5. We show a range of evidence that points to renewal rates between 0.63% and 1.25% per annum and select a level of mains renewal that is below the bottom of the 0.63% range and therefore clearly 'no regrets' whilst also demonstrating through our network analysis tools that at this level burst mains should remain relatively stable over the period.
- We describe our customer evidence on options for asset health in 6.6 as well as the feedback we have had from the Water Forum on these matters.
- These investments are not suitable for DPC or third-party funding.

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?*

b) *Has a robust cost–benefit analysis 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?*

c) *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?*

6.1. CIVIL STRUCTURES

In section 3, we explained the importance of long-term asset health and the need for investment. In section 4, we explained how we had identified which specific civil structures at treatment works would need replacing.

Our strategy aims to maintain service risk by addressing issues to our civil structures based on their condition. We will repair condition grade 5 assets as soon as it is safe, practical and efficient to do so. We will proactively repair condition grade 4 assets within five years of identifying them to:

- Be able to deliver repairs at an efficient whole life cost for our customers.
- Minimise the risk of failure of those assets and avoid the costs and impacts associated with that failure.
- Ensure that there is foresight of the required activity such that it can be efficiently funded without placing pressure on other elements of maintenance and creating inefficiency in other parts of our investment programme.

Our plan includes investment in 2025-30 to remediate all assets that we identified in our extensive survey programme as being in condition grade 4. We provide a list of all civil structures at condition grade 4 or 5 based on the survey evidence in Annex 4, and we hold the detailed information and survey report for each.

When we repair an asset, we will extend the life of the asset in the most long-term cost-efficient manner[45], normally restoring it to at least a condition grade 2 status.

In section 5.1.1, we explain how we have considered different options for meeting the need. The most effective and efficient solution is to repair the existing assets – but we have considered how different scopes might be needed, depending on the underlying condition of each asset when inspected in more detail (compared to our visual inspection). In 5.1.2, we explain how we modelled the overall cost of the programme based on these scopes and the likelihood of our worst-case, expected, and best-case options.

6.1.1 Estimating the scope and costs of interventions

We used our solutions hierarchy to consider a full range of options, to help us to make sure we selected the appropriate approach to manage cost, service, and the wider social impact now and over the long-term. In this case, applying our hierarchy is very simple: the most effective and efficient solution was to repair the existing asset.

Our condition grading exercise (see Section 4.2) provided a reasonably accurate view of condition based on a visual inspection but in some cases, it was not possible to determine the full extent or exact cause of each issue. This would require more intrusive inspections, which may involve draining down tanks (for example). While detailed inspections can be carried out during routine maintenance outages, it is not practical to conduct proactive intrusive inspections across our entire asset base. Even if we had been able to do this, assets could deteriorate further between the date of inspection and repairs made in 2025-30.

So, we would not know exactly what the scope of each repair will be until we start each project and uncover the full extent of each issue. To deal with this uncertainty, we:

- Produced a three-point estimate of potential scope required (that is, our estimate of the worst, expected, and best-case scenarios).
- Produced a cost estimate for each potential scope.
- Estimated a likelihood for each scope that it will be required when we come to deliver the project.
- Produced a programme level stochastic estimate of programme cost (by combining these costs and likelihoods).

[45] Our solution hierarchy was applied to consider alternate solutions, but it is trivial to demonstrate that repairing an existing asset is the appropriate and efficient approach.

Our three-point estimates of scope

We produced our three-point estimate of the potential scope required for each asset that requires an intervention in 2025-30 due to its condition – that is, 81 water assets and 189 wastewater assets that we had identified in condition grade 4. For these assets, we looked at three cases:

- Worst case – where the detailed inspection at the point of investment reveals the asset is in worse condition than expected and a full refurbishment or replacement is required;
- Expected case – where the detailed inspection reveals the condition of the asset is aligned to the expected condition as identified in the initial condition surveys, requiring the expected intervention; and
- Best case – where the detailed inspection reveals that the asset is in better-than-expected condition, and although an intervention would still be required, it maybe that a lower cost solution could be used to extend the asset life.

Figure 42 below provides some example solutions for the three options, to demonstrate the variation that we considered. The worst case is the highest cost solution and the best case the lowest cost solution.

FIGURE 42: EXAMPLE WORST, EXPECTED AND BEST-CASE SOLUTIONS

Site	Asset	Worst case scope	Expected case scope	Best case scope
Layer WTW	Chlorine Injection Building	Replace building with new fitted out chlorine injection kiosk with associated injection equipment	Replace building with new kiosk, re-use existing injection equipment	Replace building with new kiosk over existing slab
Hanningfield WTW	Pulsator Clarifiers	Replace all of the covers. 6 cells. Each cell 17m x 33m.	Replace 4 of the covers. 4 cells. Each cell 17m x 33m.	Remove Covers - generally covers are not required for clarification and central clarifiers are uncovered
Hexham STW	Tricking filter distribution chamber	Replace distribution chamber, allow 6 months of temporary over-pumping during construction.	Drain-down, clean out. Internal and external repairs to structure. Install an internal membrane lining. Allow for 3 months of over-pumping during repairs.	External brickwork repairs; 2 weeks of labour, materials plus scaffolding.
Aldin Grange North (Bearpark) STW	Retaining wall	Replace retaining wall with precast units. Dig out and backfill.	Build a precast panel wall against the existing wall.	Extensive patch repair; 1 week of labour and materials.

Producing our cost estimates

The scoping and costing of the programme of work included within this case is the result of a four-stage process. This process has been designed to account for the uncertainty inherent in the rate of deterioration of these civil assets between the date of survey and the date they are remediated in AMP8. As a cohort of assets we can have more confidence in the overall impact of deterioration but for an individual asset the rate is still subject to many hard to observe exogenous factors[46]. This process included four distinct groups of experts to both account for the range of skills required and to create a culture

[46] Including fluid dynamics of the asset and exposure to the elements.

of challenge and review which helps improve the robustness of scope and cost estimates. Figure 43 below show a summary of the stages of the process and the roles and responsibilities of each group in each of those stages.

FIGURE 43: SUMMARY STAGES OF THE COSTING PROCESS

Stage	1 – Civils inspection team	2 – Engineering design team	3 – Quantity surveyors	4 – Asset management & statistical analyst
1 – Three-point scope estimate	Produce inspection reports from which scope is estimated.	Produce a three-point scope estimate for each asset in scope of the programme.	Receive scopes and ensure clarity in instructions for cost estimation.	
2 – Cost estimates from cost models			Apply PR24 costing methodology to produce cost estimates.	Provide an initial light touch review and challenge.
3 – Review, challenge, update and assessment of likelihood	Review and challenge the scope and costs produced against the site knowledge. Collaborate to produce a likelihood.	Respond to challenge and update scope as required. Collaborate to produce a likelihood.	Respond to challenge and update cost estimates as required.	
4 – Monte Carlo modelling to produce programme level cost estimate		Validate the uncertainty assessments around estimates.	Validate the uncertainty assessments around estimates.	Design and run a Monte Carlo analysis.

The Monte Carlo analysis performed to estimate a programme cost uses a pseudo-random number generator within Microsoft Excel utilising Power Query to automate the selection of base data from a data store consistent with user input on the analysis to be run. The user input defines the following aspects of the model run:

- The cohort of assets to be included in the analysis:
    - The user can select either water service or wastewater service assets to provide a broad filtering.
    - The user can then select individual assets to assign to of two groups (or neither) for analysis. This allows the potential profiling of investment over two AMPs should that be required for deliverability or affordability.
- The number of iterations of the Monte Carlo analysis to be run.
- The percentile for outputs displayed.
- The uncertainty around the cost estimates produced. This approach treats each individual estimate as a normal distribution with a mean equal to the point estimate and a standard deviation defined by the user inputs as a percentage of that mean. This uncertainty is set separately for capex and opex separately and the Monte Carlo treats these uncertainties as independent[47].

[47] I.e. information on the outcome of uncertainty for a particular capex estimate gives no information about the outcome of uncertainty for opex of the same option or indeed the outcome of uncertainty for capex or opex for any other option.

The analysis produces a programme[48] level estimate of total capital and operational cost. This programme total is then allocated to individual assets based on the results of a parallel asset Monte Carlo analysis. This apportionment is performed using the percentile specified by the user inputs as illustrated in an example in Figure 44 below. This example assumes a programme of only two assets where the user has selected a 50th percentile outputs to be reported.

FIGURE 44: EXAMPLE OF PROGRAMME COSTING USING MONTE CARLO ANALYSIS

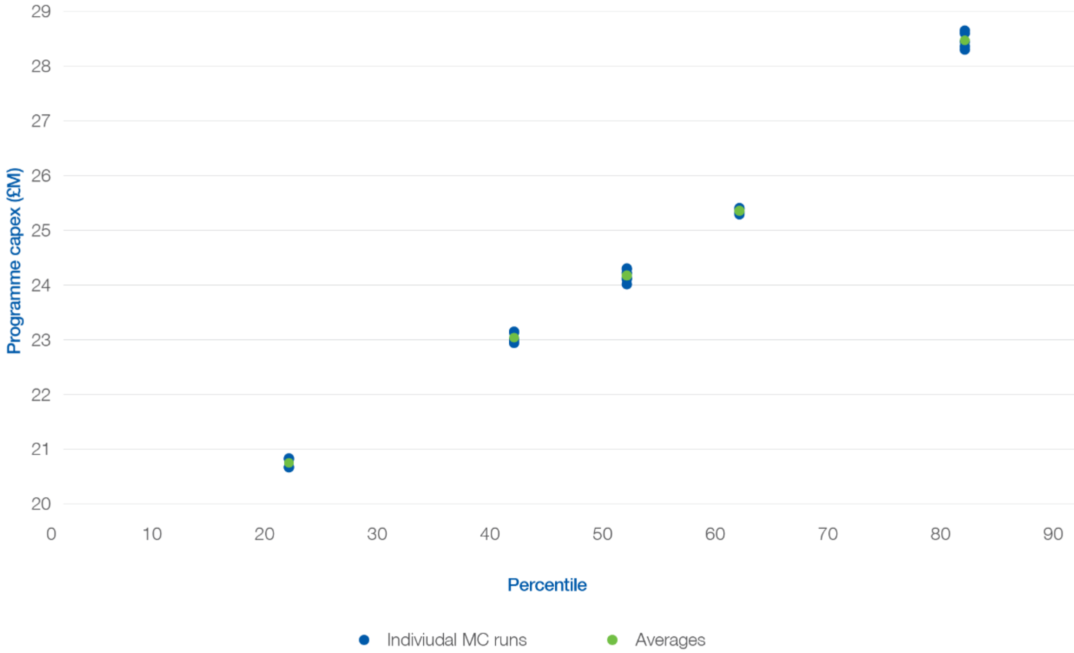
Item	Programme	Asset A	Asset B
50th percentile cost	£9m	£6m	£4m
Sum of 50th percentile assets costs	£10m		
Proportion of sum of 50th percentile asset costs		60%	40%
Proportional allocation of 50th percentile programme costs		£5.4m	£3.6m

The Monte Carlo analysis results in a 50th percentile programme capital cost of **£24.174m** to remediate the 82 identified assets in poor condition and return them to a serviceable state (condition grade 2). This was the average result of 10 separate simulations[49] each with 3,000 iterations applying a 20% standard deviation to each point estimate. This result is the value we propose to include in our PR24 investment plan.

Figure 45 below shows the impact for water on programme cost of selecting different percentiles of output from the Monte Carlo analysis. We have selected the 50th percentile as we believe it provides the fairest share of risk with our customers.

[48] The programme is analogous to the cohorts defined by the user.
[49] The spread of these 10 simulations was 1.2% from the lowest value £24.014m to a maximum of £24.305m.

FIGURE 45: WTW CIVIL ASSET HEALTH PROGRAMME COST – 20% UNCERTAINTY



We also performed a sensitivity test to demonstrate the impact of the assumption of uncertainty around the asset level cost estimates. We feel that 20% is the most appropriate choice given the costing methodology applied but the sensitivity test demonstrates that the impact of this assumption is not significant. The results of the sensitivity test are shown in Figure 46 below.

FIGURE 46: WTW CIVIL ASSET HEALTH PROGRAMME COST

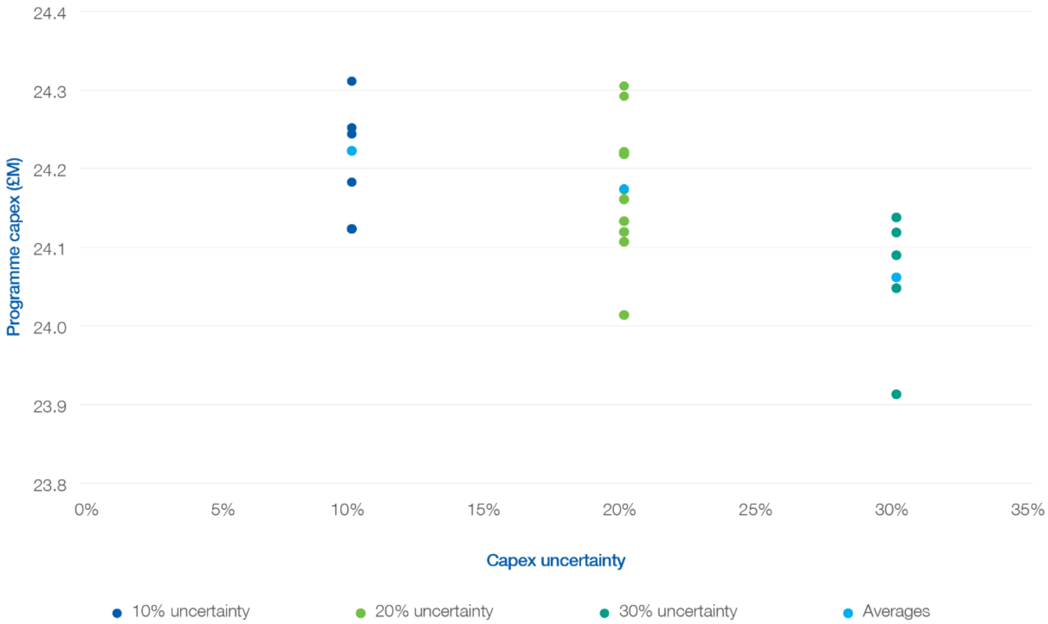
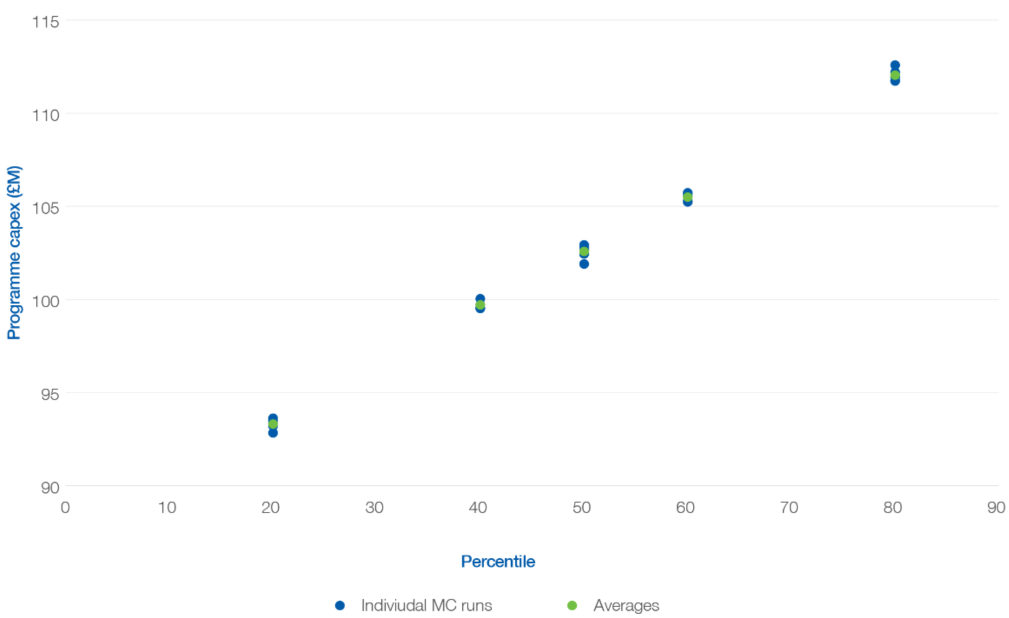


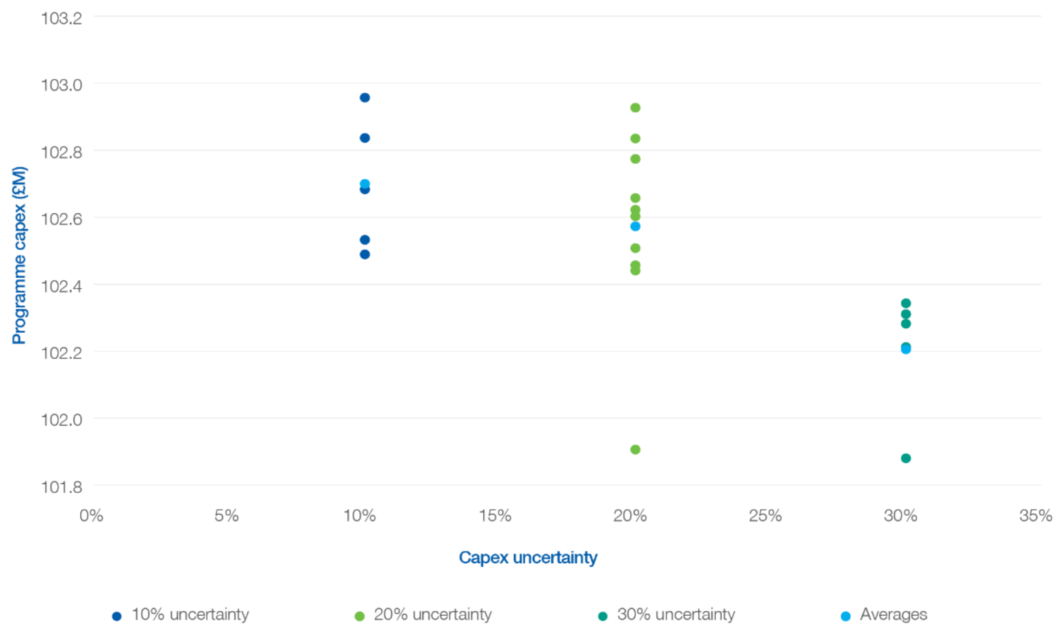
Figure 47 below shows the impact for wastewater on programme cost of selecting different percentiles of output from the Monte Carlo analysis. We have selected the 50th percentile as we believe it provides the fairest share of risk with our customers. The analysis results in a 50th percentile programme capital cost of **£102.6m** to remediate the identified assets in poor condition and return them to a serviceable state (condition grade 2).

FIGURE 47: STW CIVIL ASSET HEALTH PROGRAMME COST – 20% UNCERTAINTY



We also performed a sensitivity test to demonstrate the impact of the assumption of uncertainty around the asset level cost estimates. We feel that 20% is the most appropriate choice given the costing methodology applied but the sensitivity test demonstrates that the impact of this assumptions is not significant. The results of the sensitivity test are shown in Figure 48 below.

FIGURE 48: STW CIVIL ASSET HEALTH PROGRAMME COST



6.1.2 Selecting the right option for our business plan

We used the Monte Carlo analysis described above to produce a stochastic estimate of cost for the whole programme. This type of analysis used the likelihood and costs of each option to provide a range of estimates for the likely total costs for the programme – because we don't know which individual scopes will be required for each asset.

This programme level cost can then be proportionally allocated back to individual assets, but it is no longer directly an estimate of the cost to remediate that asset.

6.1.3 Best value solutions for customers

We could choose to make this investment in 2025-30, or we could phase this investment, delaying it to beyond 2035. To make this decision, we looked at the estimated costs of delivering these improvements in 2025-30 and waiting until 2030-35, as well as the likelihood and potential consequences if these assets were to fail.

We have used our capital maintenance allowances from PR19 to target investment in priority assets, and this has helped to maintain asset performance during this period. Despite this expenditure, we have shown that the overall performance of our long-life assets is deteriorating, and that we need additional investment.

As a result of deteriorating performance, the risks and potential consequences associated with operating and maintaining our long-lived assets is increasing. The main risks are:

- **Operational** – increasing operational activity needed to monitor and manage assets on a day-to-day basis, including impact on work planning and scheduling.
- **Customer service** – increased likelihood of key assets being out-of-service, short and/or longer-term, with an impact on our performance against our commitments.
- **Environment** – increased possibility of localised environmental damage and associated costs (including third parties).
- **Northumbrian Water** – loss of trust in our ability to maintain our assets.

Our risk framework allows us to assess the need for further investment and helps us to manage the increasing risks associated with long-life assets. As part of this, we have looked at the costs of delaying these investments beyond 2030, as well as the potential consequences of asset failure. A failure for a long-life asset can have severe consequences, particularly if this is operating near or at full capacity, with limited back-up. Although we can recover from these failures, this will often be expensive and have further consequences for others (such as environmental damage).

The proposed solution represents the best value for our customers and the environment over the long-term.

FIGURE 49: POTENTIAL COST OF DEFERRAL

Service	AMP8 programme cost (50th percentile)	Potential AMP9 programme cost (AMP8 worst case)	Potential additional cost if deferred by one more AMP
Water	£24.2m	£41.3m	£17.2m (71%)
Wastewater	£102.6m	£152.3m	£49.7m (48%)

Figure 49 shows the results of our analysis, which we explain in more detail in Annex 5. We estimate that investing in repairing these assets now would be around £67m cheaper than waiting until 2030-35.

Our programme of asset repairs and replacements at treatment works in 2025-30 represents an efficient whole-life cost for customers. We assessed this by comparing our central estimate of delivery costs in 2025-30 (or “P50”) with the costs if this were delayed until 2030-35 instead. We estimated the costs of deferring to 2030-35 by looking at the difference between the “worst case” and “expected” scopes (see section 6.1.1).

This is because we developed our “worst case” scopes to allow for:

- Uncertainty over the degree to which the asset will deteriorate[50] between the date of the survey and date at which we remediate condition in 2025-30.

[50] While we can model deterioration for cohorts of assets well, identifying the degree of deterioration in a single asset over a period of years is challenging and any forecasts would have comparatively low confidence.

- Uncertainty in the precise condition of the asset at the point of the survey when the visual inspection techniques employed are not able to fully inspect the asset.

So, the "worst case" estimates for 2025-30 then represent the "best case" starting point for any work in 2030-35, should the investment be delayed – because the asset will already have deteriorated to 2030. The true cost of deferring investment to 2030-25 is likely to be higher than this, as assets will deteriorate further between 2030 and the date which they would be repaired in 2030-35.

The costs of deferring investments will also include the consequence of assets that deteriorate to the point of failure before a repair can be delivered[51] – this includes, for example, risks of severe pollution to our water bodies or risks to the health and safety of our operational colleagues.

FIGURE 50: POTENTIAL CONSEQUENCE OF DEFERRAL

Service	AMP8 programme cost (50th percentile)	Potential consequence of failure (Minimum to maximum)	Potential impact of deferral (Minimum to maximum)
Water	£24.2m	£59.8m to £114.7m	£35.7m to £90.5m (148% to 375%)
Wastewater	£102.6m	£161.2m to £252.6m	£58.6m to £150.0m (57% to 146%)

Figure 50 shows the potential consequences of delaying these investments until 2030-35. The consequences of resolving failures and carrying out remedial work in 2025-30 are likely to be much more expensive than proactive investment in 2025-30.

This analysis shows that investing now is the best-value decision, rather than deferring to 2030-35. This is because these assets will continue to deteriorate, and it will be more expensive to either replace these in 2030-35 or tackle the consequences of failure in 2025-30.

6.2. WATER MAINS RENEWAL

The options we consider within this case relate to two dimensions of choice, namely:

- The level of mains renewal to carry out during 2020-25 (see 6.2.1 and 6.2.2).
- Targeting the mains that we should replace to maximise customer benefit (see 6.2.3)

[51] Note that whilst both potential cost of deferral estimates (AMP9 programme cost and consequence of failure) are, to a degree, additive they cannot be directly added together to produce a combined estimate.

6.2.1 The long-term efficient level of mains renewal

There is no clear evidence for one specific efficient rate of renewal, but there is sufficient evidence that we should be doing more than the historical industry rate funded through the base econometric models (see sections 3 and 4).

It is also clear that there is not necessarily one efficient rate of renewal that can be calculated for the industry, and nor will that rate remain static at the company level. It depends on water chemistry, the rate of deterioration of the different mains materials, the cohorts of mains of the different materials laid in different soil conditions and the ages of those cohorts. Deterioration of water mains can be measured against a number of service metrics, although most commonly on burst rate. Calculating the efficient renewal rate would then need to use efficient whole life costs of proactive and reactive maintenance at different levels to devise an optimised programme over time.

The annual rates of mains renewal and implied asset ages from the various sources described in section 4.4 are tabled below alongside the current industry renewals rate.

FIGURE 51: COMPARATIVE MAINS RENEWAL RATES AND IMPLIED AVERAGE MAINS AGES

Description	Annual mains renewal rate, % per annum	Implied average age of mains, years.	Source
England and Wales observed rate in the 5-year period of efficiency setting within Ofwat's base cost models	0.17	588	Ofwat's April 2023 base cost model consultation, and 2023 APRs
NWL assumed economic life of water mains assets	1.0	100	Internal company accounting
EU observed average renewal rate for drinking water infrastructure 2017-2019	1.0	100	Europe's Water in Figures, EurEau (2021)
Swedish application of deterioration modelling tools, 2011.	0.6 (distribution mains) – 0.7 (all water supply infrastructure)	143 – 166	Malm A. & Svensson G. (2011). Material and age Distribution for Sweden's WW Network and Future Renewal Needs, SVU Rapport, 13.
WICS' analysis of Scottish Water's required renewals rate to inform 2021-27 prices	0.77 – 1.25	80-130 for water mains <300 mm diameter	2019 Decision Paper, Strategic Review of Charges 2021-2027, Asset Replacement.pdf (wics.scot), page 21
WICS' analysis of Scottish Water's required renewals rate to inform 2021-27 prices	0.7 – 1.1	90 – 140 for water mains >300mm diameter	2019 Decision Paper, Strategic Review of Charges 2021-2027, Asset Replacement.pdf (wics.scot), page 21
PE pipe manufacturers asset life estimate	<1.0	>100	
Analysis of stability of PE pipes for UKWIR	0.63	160	UKWIR, 2020 Long-term aging of polyethylene pipes (ukwir.org)

What is clear from Figure 51 is that the outlier figure is the current rate of renewals in England and Wales, which is what could be reasonably assumed to be included within Ofwat's PR24 base cost models. A minimum level within the other sources of information is 0.6% per annum, implying a long-term average network age of 166 years as a maximum. This comes from practice in other jurisdictions and from the current understanding of longevity of installing today's best practice pipe materials. A conservative upper bound from these sources is 1% per annum.

We have therefore assessed a range of renewals rates above current levels to model impact on performance and understand the costs of these interventions, as described below.

6.2.2 Assessing options for different renewal rates in AMP8

Without yet having a settled multi-dimensional sector-wide agreed approach to calculating an efficient mains renewal rate, we have adopted a bottom-up approach whereby we consider different rates of renewal, using a performance risk tool, described below, to prioritise the mains we plan to replace and modelling the impact of their replacement on burst risk and risk of interruptions to supply.

We have engaged with our customers and Water Forum to understand their views both on maintaining assets and when the costs of doing so are paid for, and overall bill affordability.

We have not included the burst and interruptions to supply benefits of the mains renewal case for leakage reduction in Suffolk within this analysis, having ring-fenced the requested funding and activity which is focused on a narrower set of mains with the specific target of improving leakage. We discuss this case elsewhere in our business plan.

6.2.3 Using a performance risk tool to target renewal activity

We typically prioritise our base mains renewal programme to target maintaining or reducing the number of mains bursts. Mains bursts is an incomplete and lagging measure of asset health, and there are a number of performance measures that could drive us to prioritise different mains, such as water quality and leakage.

We have developed a more comprehensive risk assessment tool which allows us to combine the performance measures that may be improved through a mains renewal programme, using information displayed at district metered area (DMA) level and model changes in the risk to these performance metrics depending on the mains renewed. It uses a deterioration modelling tool commonly used across the UK sector, called Enterprise Decision Analytics (EDA) and was previously known as WiLCO. EDA is a whole life cost modelling platform used to model and forecast the long-term deterioration and performance of our water mains network. This is supplied by Acardis Gen (formerly SEAMS Ltd).

We model the following elements:

- Bursts performance: predicted number; and
- Interruptions to Supply Performance condition: predicted average minutes.

We are currently also developing an adjustment to the EDA modelling approach relating to improvement in leakage performance due to mains repairs. The existing leakage model, written and controlled by SEAMS Ltd, is not easily editable and leakage benefits could only be realised when all the pipes in a DMA were replaced. This does not reflect how we currently address leakage, so we are developing a new model.

EDA is able to run optimisation (linear and non-linear) scenarios to find the optimal set of interventions to achieve a specific outcome under a set of constraints. We use EDA outputs to determine the long-term investment needs for mains replacement to meet burst and interruptions performance targets.

We are expanding our own risk assessments to further inform our mains renewal activities using additional quantitative and qualitative assessments. Our tool output is illustrated in Figure 52 below. The tool considers risks to:

- Iron compliance;
- Lead compliance;
- Water quality contact risk due to flushing activities;
- Bursts;
- Interruptions to supply; and
- Leakage.

We assess these qualitatively and weight them to give a risk score for each DMA. The tool also contains more granular information at main level, which allows for interventions to be targeted at the highest risk mains within each DMA, rather than assuming all mains in the DMA need renewal simultaneously. The tool allows us to prioritise our mains renewal programme to maximise benefit for customers and is illustrated overleaf.

FIGURE 52: ILLUSTRATION OF DMA RISK ASSESSMENT DASHBOARD

identifier	DMA name	Region	Iron risk	Lead risk	flushing contacts reduction	bursts	interruptions to supply	actual bursts per km	predicted bursts per km	predicted interruptions to supply from bursts	leakage impact	Overall Score
4314	LEE CHAPEL LANE	south - essex	Unknown	High Risk	Moderate Risk	High Risk	High Risk	High Risk	High Risk	High Risk	Moderate Risk	22
4503	GREENS FARM	south - essex	Unknown	High Risk	Low Risk	High Risk	High Risk	High Risk	High Risk	High Risk	Moderate Risk	22
TY098	PAGECROFT METER DISTRICT	north	High Risk	Low Risk	High Risk	Moderate Risk	High Risk	Moderate Risk	Moderate Risk	High Risk	Low Risk	22
4501	RAMSDEN RES	south - essex	Unknown	High Risk	Low Risk	High Risk	High Risk	High Risk	Moderate Risk	High Risk	Unknown	22
DTS070	Balmoral	north	High Risk	Moderate Risk	High Risk	High Risk	Moderate Risk	Moderate Risk	High Risk	Moderate Risk	Low Risk	21
6209	MELBOURNE	south - essex	Unknown	High Risk	Low Risk	High Risk	High Risk	High Risk	High Risk	High Risk	Moderate Risk	21
WA13	CHELMSFORD ROAD	south - essex	Unknown	High Risk	Low Risk	High Risk	High Risk	High Risk	High Risk	High Risk	Moderate Risk	21
WD011	BRIDGEHILL to BLACKHILL	north	High Risk	Moderate Risk	High Risk	High Risk	Moderate Risk	Moderate Risk	Moderate Risk	Moderate Risk	Moderate Risk	21
WD065	LOUD to STANLEY SR	north	High Risk	Moderate Risk	High Risk	Moderate Risk	Moderate Risk	Moderate Risk	High Risk	Moderate Risk	Moderate Risk	21
WD219	DIPTON 9 INCH	north	High Risk	Moderate Risk	High Risk	Moderate Risk	Moderate Risk	Moderate Risk	High Risk	Moderate Risk	Moderate Risk	21
WD066	LOUD S R - ANNFIELD PLAIN	north	High Risk	Moderate Risk	Low Risk	High Risk	High Risk	Moderate Risk	High Risk	Moderate Risk	Low Risk	21
ET106	WEST CHIRTON	north	Moderate Risk	High Risk	High Risk	High Risk	Low Risk	Moderate Risk	High Risk	Moderate Risk	Low Risk	21
9040	THORNDON	south - suffolk	Unknown	Low Risk	High Risk	High Risk	High Risk	Moderate Risk	High Risk	High Risk	Low Risk	21
3911	DOWNHAM	south - essex	Unknown	Moderate Risk	Low Risk	High Risk	High Risk	High Risk	High Risk	High Risk	Unknown	21
4216	HIGH ROAD PITSEA	south - essex	Unknown	Moderate Risk	Low Risk	High Risk	High Risk	High Risk	High Risk	High Risk	Unknown	21
NT030	PONTELAND DISTRICT METER	north	Moderate Risk	Moderate Risk	Moderate Risk	High Risk	Moderate Risk	Moderate Risk	Moderate Risk	High Risk	Moderate Risk	21
DWD008	Barlow Fell	north	Moderate Risk	High Risk	High Risk	Moderate Risk	High Risk	Moderate Risk	Low Risk	High Risk	Moderate Risk	20
WD008	BRANDON VILLAGE	north	Moderate Risk	Moderate Risk	High Risk	High Risk	High Risk	Moderate Risk	Moderate Risk	Moderate Risk	Unknown	20
WD167	CHARLES STREET STANLEY	north	High Risk	Low Risk	High Risk	Moderate Risk	High Risk	Moderate Risk	Moderate Risk	High Risk	Low Risk	20
ST017	WREKENTON	north	Moderate Risk	Moderate Risk	Low Risk	High Risk	High Risk	High Risk	High Risk	Moderate Risk	High Risk	20
S47B	TOWN END FARM	north	High Risk	Low Risk	Low Risk	High Risk	High Risk	Moderate Risk	High Risk	High Risk	High Risk	20
S15E	CROSSGATE SOUTH SHIELDS	north	High Risk	Low Risk	Moderate Risk	High Risk	Moderate Risk	High Risk	High Risk	Moderate Risk	Moderate Risk	20
DTY030	Bradley Fell	north	Moderate Risk	High Risk	Moderate Risk	Moderate Risk	Moderate Risk	Moderate Risk	High Risk	High Risk	Unknown	20
WD098	FLINT HILL TO BURNHOPEFIELD	north	High Risk	Low Risk	Low Risk	High Risk	High Risk	Moderate Risk	High Risk	High Risk	Low Risk	20
ET013	SEGHILL	north	High Risk	Moderate Risk	High Risk	Moderate Risk	Moderate Risk	High Risk	High Risk	Low Risk	Low Risk	20
TY188	WARKSHAUGH TO SNOGGYGATE METER DISTRICT	north	High Risk	Low Risk	Moderate Risk	High Risk	High Risk	Moderate Risk	Moderate Risk	High Risk	Low Risk	20
WA5	LOWER BEDFORD	south - essex	Unknown	Moderate Risk	Low Risk	High Risk	High Risk	High Risk	High Risk	High Risk	Low Risk	20
4218	BASIL12	south - essex	Unknown	Moderate Risk	Low Risk	High Risk	High Risk	High Risk	High Risk	High Risk	Unknown	20
4706	VICTOR	south - essex	Unknown	High Risk	Moderate Risk	Moderate Risk	Moderate Risk	High Risk	High Risk	High Risk	Unknown	20
3707	THUNDERSLEY RES ZONE	south - essex	Unknown	Moderate Risk	Low Risk	High Risk	High Risk	High Risk	High Risk	High Risk	Unknown	20
DUMMY12	DGRAYS1	south - essex	Unknown	High Risk	Low Risk	High Risk	High Risk	Moderate Risk	High Risk	High Risk	Moderate Risk	20
DUMMY2	DTHAMES	south - essex	Unknown	High Risk	Low Risk	High Risk	High Risk	Moderate Risk	High Risk	High Risk	Low Risk	20
DUMMY32	DCOLDTOWER	south - essex	Unknown	Moderate Risk	Low Risk	High Risk	High Risk	High Risk	High Risk	High Risk	Low Risk	20
WD225	TOFT HILL TO THICKLEY	north	High Risk	Low Risk	High Risk	Moderate Risk	High Risk	Low Risk	Moderate Risk	High Risk	Low Risk	20
TY077	PRUDHOE WEST	north	Moderate Risk	Low Risk	High Risk	High Risk	Moderate Risk	Moderate Risk	High Risk	Moderate Risk	Low Risk	20
WD088	PELTON BOC	north	High Risk	Moderate Risk	High Risk	Moderate Risk	Moderate Risk	Moderate Risk	Moderate Risk	Moderate Risk	Unknown	20
WD049	GRANGE TERRACE	north	High Risk	Moderate Risk	High Risk	Moderate Risk	Moderate Risk	Moderate Risk	Moderate Risk	Moderate Risk	Unknown	20
ST011	LEAM LANE	north	Moderate Risk	Low Risk	High Risk	Moderate Risk	Moderate Risk	High Risk	High Risk	Moderate Risk	Unknown	20
ST006	FELLING VBC DISTRICT METER	north	Moderate Risk	High Risk	Low Risk	Moderate Risk	Moderate Risk	High Risk	High Risk	Moderate Risk	Moderate Risk	20
ST036	WEST WINLATON	north	Moderate Risk	High Risk	Moderate Risk	High Risk	High Risk	Moderate Risk	Moderate Risk	Low Risk	Moderate Risk	20

Source: NWL DMA risk assessment dashboard

For 2025-30, we aim to improve our quantification of the broader risks along with our understanding of the rate of change of these risks, while documenting the realised benefits of our mains renewal programme. Using this balanced assessment of risks will allow us to deliver a long-term renewal programme that looks beyond any individual regulatory incentive to ensure that we consider a more holistic view of asset health.

Using this prioritisation tool, we have calculated a modelled risk impact on burst rates and interruptions to supply greater than three hours. We expect that some minor improvement in performance, in particular burst rates, will be delivered immediately by the renewal programme. However, we are forecasting improvements in measures from a sustained increase in mains renewal to be more apparent in AMP9 and beyond as the rate of improvement in performance due to the renewals exceeds the rate of deterioration in performance within the rest of the mains installed.

6.2.4 Mains renewal options considered

We considered different increased rates of renewal and applied them to our prioritisation tool to model the impact on burst and interruptions to supply risk. We also modelled a “do nothing” scenario to show the modelled increase in risk that underlies our renewal programme. The options we considered are described as follows.

FIGURE 53: DESCRIPTION OF THE OPTIONS WE MODELLED

Option	Description	Length of main to be replaced in AMP8 from base, km	Additional length of main to be renewed in AMP8 above base, km	Total length of main renewed in AMP8, km
A	Do nothing – a modelled scenario of undertaking no further mains replacement activity in the rest of AMP7 nor any in AMP8	0	0	0
B	Maintaining a constant 0.17% renewals rate i.e. assumed to be funded in base	223	0	223
C	AMP8 renewal rate of 0.37% (0.2% above base level)	223	263	486
D	AMP8 renewal rate of 0.47% (0.3% above base level)	223	394	617
E	AMP8 renewal rate of 0.57% (0.4% above base level)	223	525	748
F	AMP8 renewal rate of 0.67% (0.5% above base level)	223	657	880

6.2.5 Mains renewals Options appraisal

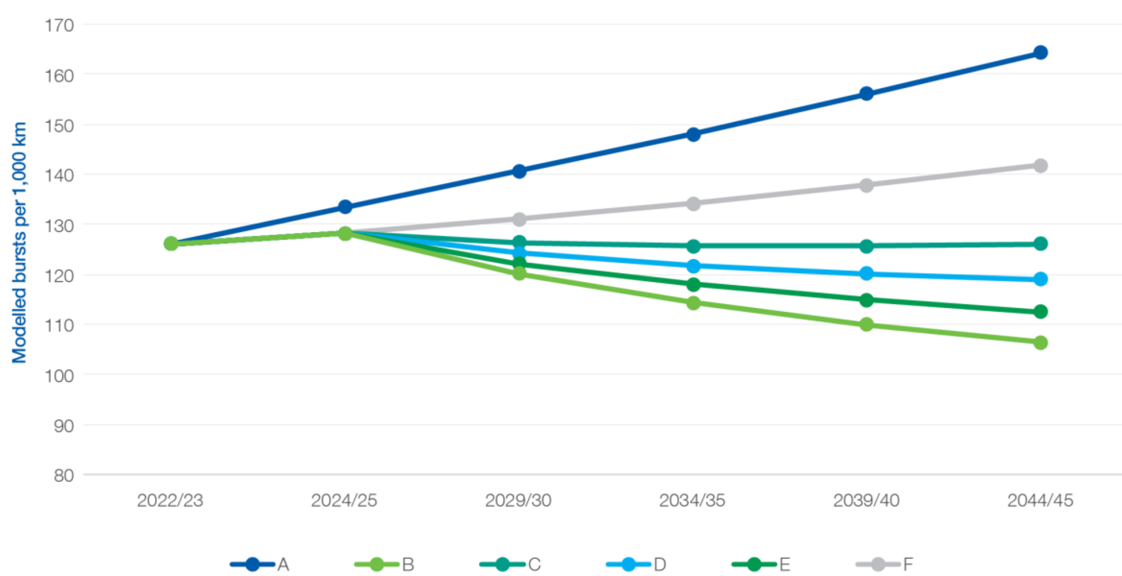
We estimated the costs and primary benefits of the options that we were considering, to support our decision on which level of renewals to undertake on a ‘no regrets’ basis in 2025-30. We used bursts as the primary asset health measure as it is the most mature and commonly used by industry and Ofwat for understanding the state of our assets. The starting point for calculating benefits is our company level modelled burst risk with today’s mix of pipe materials and age cohorts (which is 126.03 bursts per 1,000km).

The modelled burst benefits of the options are shown in table and graphical form below when extending the option rate of renewal over the long term.

FIGURE 54: IMPLIED ASSET AGE AND MODELLED BENEFITS OF OPTIONS

Option	Implied average asset age	Modelled burst risk/ 1000 km 2022/23	Modelled bursts/ 10000 km, 2029/30
A	-	126.03	140.62
B	588	126.03	130.95
C	270	126.03	126.37
D	213	126.03	124.21
E	175	126.03	122.11
F	149	126.03	120.08

FIGURE 55: MODELLED BURST RISK IMPACT OF EACH OPTION



Source: NWL analysis using performance and risk modelling tool

The additional costs, over and above that assumed to be allowed for in the base cost model, are shown for each option in Figure 55. These are based on an efficient company level unit cost rate (£273.70/metre). We explain how we derived this unit rate in section 0.

FIGURE 55: COSTS OF EACH OPTION CONSIDERED

Option	Efficient costs of the additional mains renewal programme, £m (2022/23 prices)
A	0
B	0
C	71.89
D	107.83
E	143.77
F	179.71

Our primary aim in selecting the option for additional renewals is to arrest the modelled decline in performance forecast to occur over AMP8. Continuing to renew mains at the rate we calculate is within base cost allowances (Option B) does not meet that primary aim. An increase in renewals above the base rate is required in order for performance not to deteriorate. Figure indicates that in order to maintain a stable modelled burst rate, a renewal rate as provided by Option C is the minimum level of renewals which will deliver our primary aim over the long term. Options D, E and F demonstrate an improvement in bursts from the level of mains to be renewed in AMP8 and beyond.

Our secondary aim is to move towards a long-term asset life that matches international practice and our understanding of the asset life of the current materials we use for new and replacement mains. This would set up a smooth profile of investment into the future and avoids storing up a particular peak of asset replacements for future periods. Option E takes us to a position of an implied average asset age of 175 years, which is reasonably close to the 160-year estimated life of PE pipes as shown in **Error! Reference source not found.**.

Options C, D or E are those that deliver both our primary aim and increasingly our secondary aim.

6.2.6 Affordability and deliverability have constrained our option selection

Customer research on bill profiles and phasing suggests that our customers do not support delaying investment and putting more of the burden on future customers. However, customers have also informed us that affordability of future water bills is a key concern for many of them at PR24.

Our experience from the S19 programme in the 1990s and 2000s has taught us that it takes time for the supply chain to be able to meet capacity requirements when there is a large increase in volumes. It is vitally important that safety and public health are not compromised by short-circuiting the training required by our workforce and the supply chain before they carry out mains renewal work. This case assumes we are not in a unique position, and we therefore expect a step up in mains renewal work may be needed across England and Wales.

On the grounds of both affordability and deliverability, we therefore consider it prudent to plan for a relatively modest increase in renewal rate that meets our primary aim. On this basis our **preferred option is Option C** for AMP8.

6.2.7 Impact of our preferred option on pipe age and materials

We have assessed the impact of Option C, our preferred option, on mains materials and age cohorts using the EDA model outputs, comparing it with Option B. Figure 6 and Figure 67 illustrate that our modelled renewal programmes for Options B and C respectively target mostly CI mains with the majority of them within an age band of 43-102 years old. They also show that the proportion of mains that are PE increases due to the renewal programme. Option C increasingly selects AC mains.

FIGURE 66: CHANGE IN MAINS MATERIAL AND AGE BANDS FROM OPTION B – RENEWING MAINS AT 0.17% P.A.

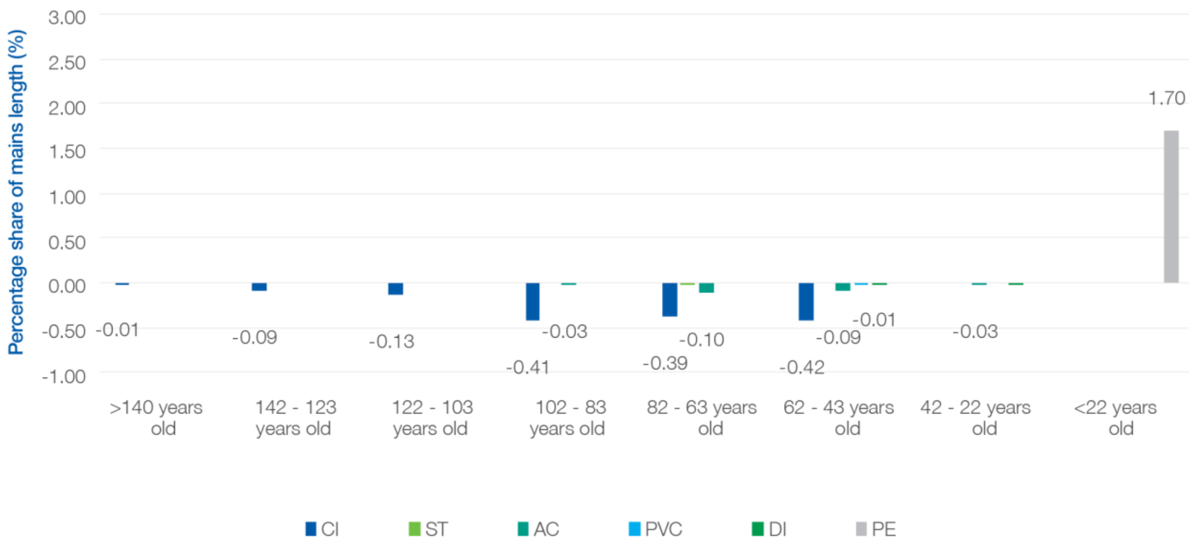
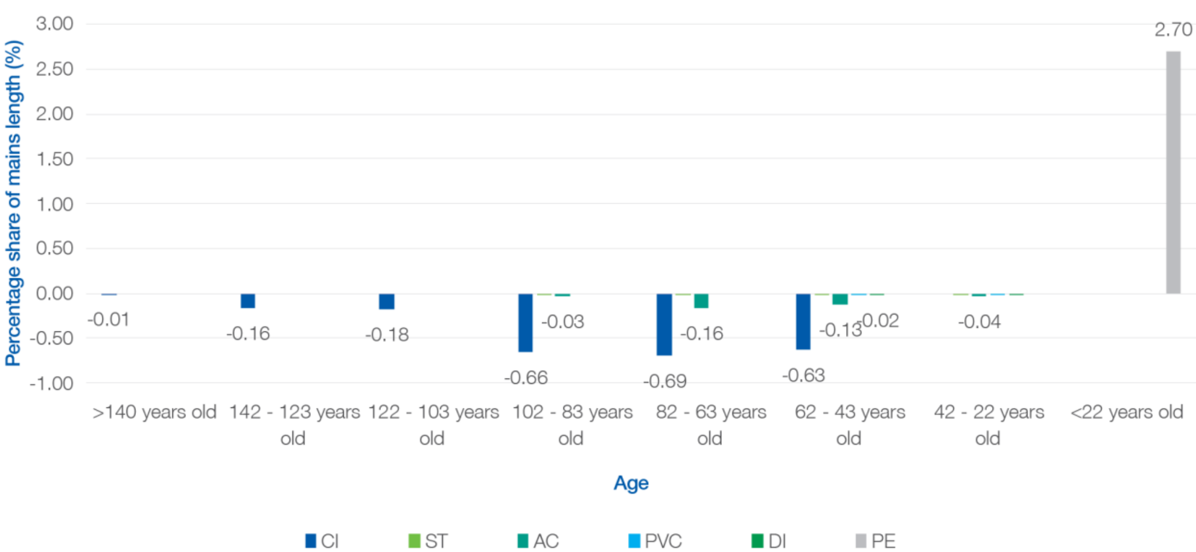


FIGURE 67: AMP8 CHANGE IN MAINS MATERIAL AND AGE BANDS FROM OPTION C – OVERALL RENEWAL OF 0.37% P.A.



6.3. CUSTOMER EVIDENCE

g) 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 described our customer engagement in Section 3.6, including how we used customer views to select the proposed solution. These discussions were about both scale/timing and the right solutions to the problem.

We also describe how we used our People Panels to help tackle the difficulties of engaging with customers on this topic.

Resilience is a difficult topic to engage customers on – as it is difficult to expect customers to take an informed view about future risks and the right balance between acting now and accepting risks for the future. **Research by CCW and Blue Marble** has found that one of the least appropriate areas for consumer research is "very long-term planning and future scenarios".

This has proven difficult to research using quantitative surveys. For example, since Q1 2022 we have asked participants in our quarterly household tracking research which of 10 areas should be our business plan priorities. In four out of five quarters (Q1 2022 – Q1 2023) ''***Better reliability by replacing infrastructure and doing more maintenance'*** ranked 8th out of 10 priority areas tested.

However, it is important that customers are involved in making these decisions – and so we have used different research methods to improve our understanding. At PR19, we commissioned DJS research to understand customer views on resilience, asset health and long-term affordability (see Figure 3.13) – and customers felt that we should take a balanced to proactive approach. For PR24, our People Panels have helped to provide a more informed view about asset health and resilience, with customers having several research sessions to understand and discuss views on the long-term approach, their views on asset health, and then several iterations of specific investment proposals and choices. This increased level of detail has supported improved decision making for our asset health investments at PR24.

We set out broad customer views on asset health in section 0. This describes our decision making on asset health in general, but this does not necessarily show how we should target our investments. Mains renewal delivers benefits for reduced leakage and improved water quality, so we summarise our customer research in these areas below.

Leakage Reduction

Our customers say that reducing leakage is one of the most important priorities for them (**prioritisation of common PCs**, NES44).

In our most recent Domestic Tracking (2022-23) research, we asked customers which of 10 areas should be our business plan priorities. 'Repair leaks more quickly' ranked between 3/10 to 7/10 across the period with scores in the North East tending to be lower compared to Essex and Suffolk scores. In the Retailer and Non-Household Research 2022 customers allocated the highest score for 'Reducing leakage from the network'.

Water Resources East Customer Engagement customer told us that current leakage levels are seen to be too high, but customers agree that a 50% reduction is acceptable. Many customers spontaneously suggested that 10% leakage would be a pragmatic figure; a significant reduction while appreciating that 0% leakage is not realistic. However, they considered timeframe of 2050 as too far out, preferring 2030 as a better target. This aligns with our plans to address leakage though water mains renewal in AMP 8.

Customer feedback suggests that there is a relatively limited appetite for paying more for leakage improvement, which may reflect customer expectations that pipes which do not leak are an expectation of base service.

Drinking Water Quality

Drinking water quality is consistently rated amongst our customers' highest priorities (prioritisation of common PCs, NES44).

In Ofwat's cost-of-living study Wave 3 in 2023, approximately six in ten (58%) billpayers selected good quality drinking water' as a top factor, placing this attribute 1st out of the 7 factors presented. In all four rounds of Domestic Tracking 2022 research and Q1 2023 'Maintaining high standards on clean, clear and good tasting water' achieved the highest average score of all areas tested.

Feedback from the Water Forum

The Water Forum recognised that mains replacement or renewal can deliver long-term sustainable benefits for several performance measures which are important to customers (such as water quality contacts, interruptions, and leakage). However, this is expensive and tends to be deprioritised as an intervention in favour of short-term operational interventions. The level of mains replacement has fallen in recent years, which partly reflects the industry finding more innovative operational solutions to improve performance, but which may be starting to reach its limits.

The Water Forum accepted our recognition that adequately funding asset health is a wider problem for regulated companies, in part exacerbated by the five yearly price review cycles which can create incentives to put off such investments into the future, given continuing affordability concerns and competing pressures for investment.

Further, they agreed that a completely new approach to cost assessment is needed (now impractical for PR24), as well as a rethink of the current asset health outcome measures. More work is required to better understand the benefits, probably on a cross-industry basis.

The Water Forum challenged us specifically on mains renewal, with their expert advisor suggesting that we consider a higher replacement rate of 1% per year, as this more closely matched a realistic asset life.

"*If the rate can be increased to something closer to 1% (a 100-year implied life) then that would feel a more sustainable long-term rate. I am pleased to see NW considering this and would add my strong support for this because in the long-term it will be essential to sustainably achieve outcomes customers value…"*

"I am encouraged by the proposals being considered by NW in relation to mains renewal and urge that every effort should be made to develop and articulate a well-considered proposal in the AMP8 business plan". (Water Forum expert advisor, June 2023)

We have responded to this challenge by considering more mains renewal in 2020-25, increasing our overall mains renewal rate to that implied by the base cost models (0.17% annual renewal rate) – and further increasing this to a higher rate in 2025-30 (as set out in this case). The Water Forum supports our case because it is essential to sustainably achieve the long-term outcomes that customers value.

The Water Forum has also suggested that we propose a different regulatory approach, for example an incentive regarding efficient investment in mains renewal, beyond the base level.

Customer support for our options

In our **qualitative affordability and acceptability research** (NES49), we asked our customers about three options for asset health investments:

- Do nothing over and above usual expenditure (and we noted the risk of more pollution incidents, supply interruptions, and deteriorating water quality).
- A "medium" investment – in water and wastewater treatment works (£6.24 on bills in the North East; £5.48 in Essex and Suffolk).
- A "higher" investment – to tackle potential future problems, including increasing our replacement rate of mains. We noted that the benefits were mostly longer term (£11.41 on bills in the North East; £9.01 in Essex and Suffolk).

Most customers thought that a medium investment was appropriate, with some customers preferring the higher phasing option. This was because the improvements to assets would benefit future generations.

This research was based on an estimate of £110m of investment in asset health, which we described to customers as a "must do" investment (as our "medium" option). In addition to this, our "must do" plan included £123m to tackle water quality risks through asset health investments (which we had identified through the early stages of our HazRev programme). Our final enhancement case includes £112m of investment at water and wastewater treatment works, broadly consistent with our qualitative research, and £74.4m of investment in mains replacement – compared to £90m of investment to tackle water quality risks which we have removed from our plan (and will deliver from base expenditure).

This means that we have been able to include mains replacement as well as our civil assets programme within our business plan at a slightly lower cost than customers had supported – and have been able to accommodate those customers who preferred a higher phasing option by including some increase to mains replacement.

Customers told us that they wanted to see the impact of this investment and understand that this had been made. We have introduced our PCD to protect customers and to provide this visibility.

Our **line-of-sight document** (NES45) discusses customer views on asset health in more detail.

6.4. OPPORTUNITIES FOR DPC

g) Has the company appropriately considered the scheme to be delivered as Direct Procurement for Customers (DPC) where applicable?

Water mains and civil structures on existing treatment works lie at the heart of our regulated activities, and activities to renew them are dispersed throughout our network and they would not be 'discrete'. The asset health enhancement programme is also not sufficiently material to be considered 'DPC by default' with costs below the £200m totex threshold. Its overall size, dispersed nature and integration to our operational activities, existing assets and core functions means it is not suitable for us to promote through DPC.

6.5. OPPORTUNITIES FOR THIRD PARTY FUNDING

f) Has the scale of forecast third party funding to be secured (where appropriate) been shown to be reliable and appropriate to the activity and outcomes being proposed?

We do not anticipate any ability to ask for third party funding for any mains renewal or civils asset maintenance or renewal activity, as these are about repair and replacement of our assets with limited wider benefits.

7. COST EFFICIENCY

- This section summarises how we have ensured that our costs remain efficient.
- Section 7.1 provides independent benchmarking evidence which demonstrates that the unit costs of our mains renewal case are efficient in comparison to other companies.
- Section 7.2 explains the Monte Carol analysis we have undertaken of our civil structure costs to arrive at the preferred cost in our case and also highlights the benchmarking Mott Macdonald have completed on our existing cost curves highlighting in particular those structures which are in the basket of assets covered by our civil structures investment. This confirms our costs to be efficient.
- Independent cost assurance of our enhancement cases has been undertaken by Mott Macdonald.

b) Is there evidence that the cost estimates are efficient (for example using similar scheme outturn data, industry and/or external cost benchmarking)?
c) Does the company provide third party assurance for the robustness of the cost estimates?
d) Is there compelling evidence that the additional costs identified are not included in our enhancement model approach?
e) Is there compelling evidence that the allowances would, in the round, be insufficient to account for evidenced special factors without an enhancement model adjustment?

7.1. MAINS

7.1.1 Benchmarking approach

We provided to Mott MacDonald information regarding the key characteristics of our mains network across all regions we serve. The characteristics included:

- Pipe diameters
- Pipe materials
- Proportions of surface type for verge/field, footpath and road

For our Essex region we also provided a breakdown of the historical proportions of mains laying techniques split between: pipe bursting (PB), pipe insertion (PI), directional drilling (DD), and open cut (OC).

To provide competitive benchmark rates, Mott MacDonald gathered data from three water and wastewater companies of comparable scale and operating model to Northumbrian Water. A matrix of rates was devised to enable costs for each diameter of pipe and weighted twice. One weighting was by the surface type (verge, footpath, road), and the other by the pipe laying technique (PB, PI, DD and OC). Rates were also adjusted by location factor to align the benchmarks to our northern (NWL) and southern (ESW) regions. This was done using the BCIS location factors which reflect variances in labour, plant, and materials costs.

Not all comparators had rates for every combination of pipe diameter and pipe laying technique, but the matrix method gave an equal 'weighting' to each data source as far as possible.

The benchmarking has used the following assumptions:

- All mains are replaced with PE pipe (an assumption validated by us as being in accordance with our policy).
- Rates are inclusive of standard pipe fittings and wrap.
- Rates are exclusive of contractor and client overheads.
- Assumed that replacement of mains will be in keeping with the existing distribution of pipe sizes (i.e. all diameters face equal likelihood of replacement and the existing network proportions are used in weighting the composite rate).
- Assumed that the technique proportions and surface proportions for Essex are transferrable to our other regions.

7.1.2 Benchmarking results

Using the approach to benchmarking described above, Mott MacDonald's provided the following results for our two regions.

FIGURE 58: MOTT MACDONALD'S NORTHERN (NWL) REGION BENCHMARKING RESULTS, £/M 2022/23 PRICES

NWL		27%	19%	46%	8%	Weighted Rates £/m
Diameter	Network %	PB	PI	DD	OC	
Unknown	0.7%	£ 0.71	£ 0.52	£ 0.76	£ 1.27	£ 0.74
<75	8.6%	£ 8.59	£ 6.30	£ 9.21	£ 15.33	£ 8.98
75-150	56.8%	£ 64.98	£ 47.37	£ 66.23	£ 109.81	£ 65.80
150-300	22.0%	£ 63.49	£ 42.32	£ 49.35	£ 64.67	£ 53.06
300-600	7.7%	£ 48.27	£ 37.35	£ 39.34	£ 50.16	£ 42.24
>=600	4.2%	£ 30.87	£ 26.48	£ 28.10	£ 40.45	£ 29.53
	100%	**£ 216.92**	**£ 160.33**	**£ 192.99**	**£ 281.69**	**£ 200.34**

TABLE 59: MOTT MACDONALD'S ESSEX AND SUFFOLK (ESW) BENCHMARKING RESULTS, £/M 2022/23 PRICES

ESW		27%	19%	46%	8%	Weighted Rates £/m
Diameter	Network %	PB	PI	DD	OC	
Unknown	0.7%	£ 0.35	£ 0.26	£ 0.38	£ 0.63	£ 0.37
<75	8.6%	£ 3.33	£ 2.44	£ 3.57	£ 5.95	£ 3.48
75-150	56.8%	£ 69.41	£ 50.59	£ 70.75	£ 117.29	£ 70.28
150-300	22.0%	£ 85.73	£ 57.14	£ 66.63	£ 87.32	£ 71.64
300-600	7.7%	£ 59.34	£ 45.91	£ 48.37	£ 61.66	£ 51.93
>=600	4.2%	£ 30.66	£ 26.30	£ 27.90	£ 40.17	£ 29.32
	100%	**£ 248.82**	**£ 182.65**	**£ 217.60**	**£ 313.03**	**£ 227.02**

We then applied the above benchmarked weighted rates of £200.34/m for NWL and £227.02/m for ESW to our mains renewal case, so that costs per meterage is displayed together to explore the impact on the programme level unit cost. In terms of regional split, we have assumed investment expressed in km will be 66.67% in NWL and 33.33% in ESW. This split is consistent with the lengths of network within the two geographical areas meaning we are working on the assumption that our mains renewal will target all areas equally. Applying this regional weighting results in a company level unit cost of £209.23/m before the addition of any company and contractor overheads.

Applying overheads to benchmarked costs

Mott MacDonald has benchmarked industry costs excluding company and contractor overheads. In order to generate a cost for the business plan that included overheads our initial approach was to apply an uplift to direct costs for overheads consistent with the uplift applied to our wider portfolio of capital projects. However, we reviewed this decision and concluded that the scale and complexity of many of these wider capital projects is much greater than that of our mains laying programme. As the majority of mains renewal we expect to carry out in AMP8 for similar pipe diameters of our current AMP7 mains renewal programme, we used an outturn observed overhead rate from our 2022/23 mains renewal programme of 30.7%. Our mains laying programme overheads include for design, supervision, planning and administration.

We have not included any further uplift for risk or uncertainty as we have not historically applied such uplifts to any of our mains renewal programmes.

Figure 60 presents the results of benchmarking enhancements with inclusion of overheads at 30.7%.

FIGURE 60: BENCHMARKED COSTS INCLUDING OVERHEADS

AMP8 Cost £m					
Region	Unit Rate £/m	AMP8 Total Km	AMP 8 Cost £m		
			NWL	ESW	NWG
NWL - 66.67% of mains renewal (Km)	261.84	335.37	87.81		
ESW - 33.33% of mains renewal (Km)	296.72	167.66		49.75	
Total NWG	273.47	503.03			**137.56**

This shows the unit rate at the company level which we are using throughout this business case of **£273.47 per metre** of mains renewed.

Cost efficiency third party assurance

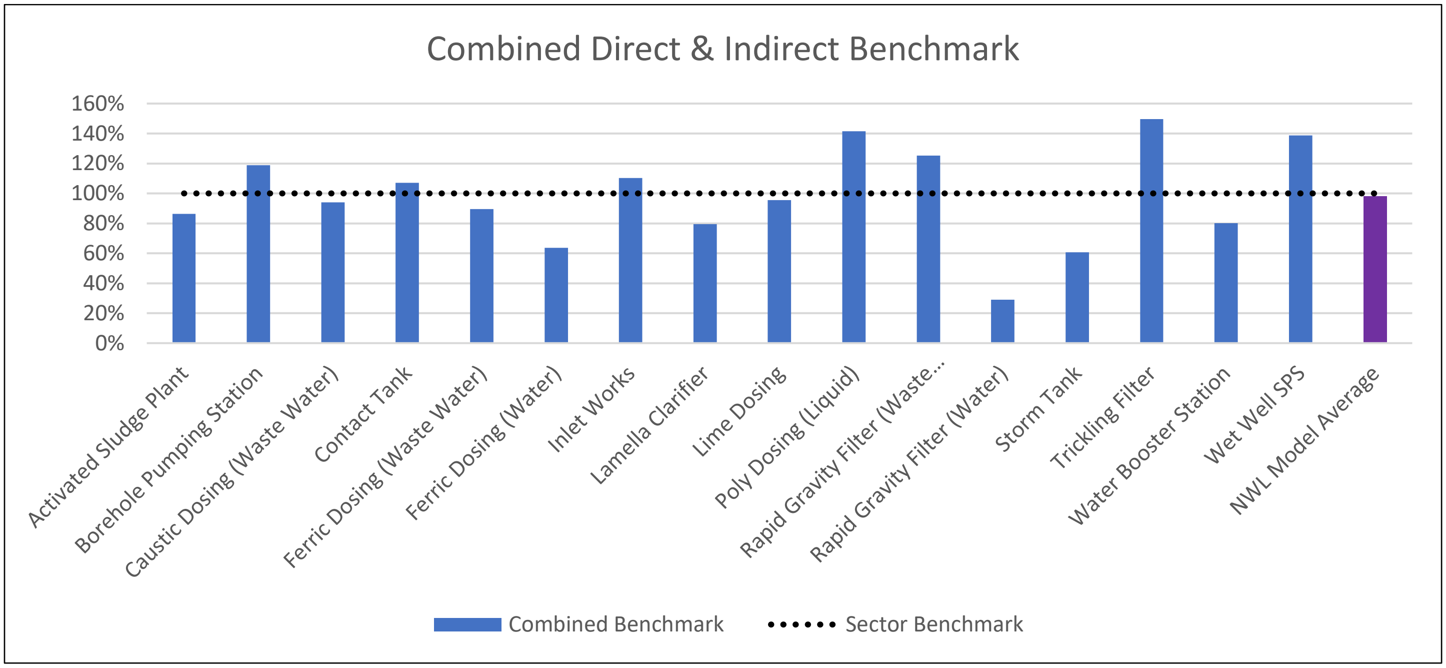
We commissioned Mott MacDonald to undertake this benchmarking exercise based on outturn cost information from other companies and costing from their database of costs. By applying this independent view of costs to inform our case, we have demonstrated the costs we are developed through a process that demonstrates a high level of third-party assurance.

7.2. CIVIL STRUCTURES

7.2.1 Benchmarking

To benchmark the efficiency of the civil structures costs we have relied upon the "pre-estimation" benchmarking carried out by Mott Macdonald. This compared our cost curves used to estimate costs for capex schemes against the curves of other companies and also included benchmarking of indirect costs. The chart below summarises the overall finding from this work that our cost curves were 2% under the industry benchmark for comparable items.

FIGURE 618: MM RESULTS OF PRE-ESTIMATION BENCHMARKING OF DIRECT AND INDIRECT COSTS



Source: Mott Macdonald pre-estimation cost benchmarking

Within these areas of work, some are more civils focussed and involve similar concrete tank structures to those primarily being considered within this enhancement case. In particular, these more similar projects show that:

- For contact tanks, we were 107% of the industry benchmark; and
- For storm tanks, we were 61% of the benchmark.

Taking the average of these 2 civils focused areas of work would put us at 84% of the average suggesting that our costs overall are efficient for civils type works as well as being below the average for a wider range of projects which will all involve civils work to some degree.

8. CUSTOMER PROTECTION

- Sections 8.1 and 8.2 provide details of our proposed Price Control Deliverables (PCDs) which would protect customers. We propose to return funding to customers in the event that we fail to deliver the proposed investments and outcomes. We develop unit rates to return investment to customers in the event of under delivery for our mains renewal case and civils cases, these are based on the efficient costs we have proposed but for civil structures we use a series of bands for the investment given that the scale of activity will vary depending on the condition of each structure.
- We further commit that no funding will be requested via these cases should NWL fail to spend its base funding allowances in full and that if we are able to deliver these investments for less than the costs proposed (i.e. we outperform the proposals) then we will simply reinvest the NWL outperformance value on additional maintenance activity.
- Finally, we commit to maintaining a strong AMMA rating and retaining our ISO 55001 accreditation throughout the period or returning remaining funds to customers.

a) Are customers protected (via a price control deliverable or performance commitment) if the investment is cancelled, delayed, or reduced in scope?
b) Does the protection cover all the benefits proposed to be delivered and funded (e.g., primary, and wider benefits)?

8.1. PROPOSED PRICE CONTROL DELIVERABLE - CIVIL STRUCTURES

Delivering the programme of civil structure maintenance we have proposed is in the best interests of our customers, but we also recognise that it is important to protect customers in the event that the investment is cancelled, delayed or reduced in scope. The ability to access and repair these assets may be impacted by unforeseen circumstances such as supply chain availability or failure of other assets reducing resilience such that we cannot take civil assets offline for maintenance. We will be proactive in managing these risks as efficiently as possible, but the Price Control Deliverable (PCD) we propose here will protect customer interests in any event.

8.1.1 Description of PCD

We commit to deliver the proposed programme of civil asset maintenance for both our WTW and STW sites; to enable this delivery we are requesting additional funding of £17.8m and £94.4m respectively. The full list of 81 WTW assets and 189 STW assets that are included in our proposed programme is included in Annex 4; this list sorts each asset into a band based on the 50th percentile of cost proportionally allocated from the programme level cost output from the Monte-Carlo analysis discussed in Section 6.1.

For each of these listed assets where we fail to complete investment which returns the asset to condition grade 2 (or better) before 1 April 2030, we will return to customers the average cost of assets in the cost band for that service. We propose that the value of any returns due to customers be made through a net present value neutral adjustment to revenue limits in AMP9. We propose that the maximum value returned to customers be capped at the value of the adjustment we are seeking; £17.8m for water and £94.4m for wastewater. The application of this cap does not in any way limit the protection to customers interests because if it were ever reached the full adjustment would be neutral in value, that is, nothing lost or gained for customers.

Figure 62 below summarises the banding and unit penalty rate for under-delivery in each service we propose.

FIGURE 62: PROPOSED BANDINGS AND UNIT COST PCD FOR CIVIL ASSETS ENHANCEMENT

Asset banding	Water		Wastewater	
	Number of assets	Penalty	Number of assets	Penalty
£10,000 or less	9	£0.006m	14	£0.006m
£10,001 - £50,000	17	£0.023m	79	£0.025m
£50,001 - £250,000	37	£0.133m	56	£0.108m
£250,001 - £1,000,000	15	£0.496m	18	£0.533m
£1,000,001 - £2,500,000	1	£1.228m	13	£1.582m
£2,500,001 - £5,000,000	0	n/a	3	£3.784m
£5,000,001 - £7,500,000	2	£5.072m	2	£7.029m
More than £7,500,000	0	n/a	4	£9.731m

8.1.1 Output measurement and reporting

We will report on delivery each year as part of the Annual Performance Report (APR) process. Reporting of completion of each asset delivered in the reporting year (that is, that it has been returned to condition grade 2 or better) will be assured by a visual inspection of the asset by an independent qualified civil engineer. Note that assets reported and assured as complete will not be subsequently re-visited and re-assured in each subsequent year.

8.1.1 Conditions on Allowance

We commit to spend all of our capital maintenance allowance in the 2025-30 period to be able to access the additional funding, and any shortfall would be deducted from this enhancement case funding.

Should we be able to achieve the civil structures investments as set out in this enhancement case for less than the allowances stated then we will reinvest any available monies in further capital maintenance investments but cost overruns against these cases will be addressed through cost sharing.

We will retain a minimum asset management competency, as measured by the asset management maturity assessment (AMMA) rating across the AMP8 period of 'competent' and will also retain our ISO 55001 accreditation throughout the period to demonstrate that we are managing our assets effectively. Our latest assessment confirms we meet these requirements today. We commit to carrying out an independent assessment of AMMA in 2027-28 to confirm our rating for the purposes of this PCD, in addition to participating in any other assessments that are carried out across the sector between 2023/24 and 2027/28 and to continue to undertake our ISO 55001 accreditation via AFNOR. Should we fall below 'competent' rating, as measured using the AMMA process in place in 2023/24 or lose our ISO accreditation we will return to customers any funds for civil asset health requested in this case that are unspent at that point.

8.1.1 Assurance

We will use our APR assurers to provide annual assurance of the completed milestones and forecast of likely outturn position at 31 March 2030 for our PR29 business plan.

8.1.2 PCD Payment Rate

The PCD penalty rates are as set out in Figure 62 above.

8.1.3 Impact on performance commitment levels (PCLs)

We do not anticipate any material impact on performance commitment levels from the additional funding in AMP8. This is a long-term asset health matter and this programme is not focused on making an immediate improvement to performance metrics, but rather addressing underlying risks to asset health.

8.2. PROPOSED PRICE CONTROL DELIVERABLE - MAINS RENEWAL

We recognise that it is important to protect customers if the investment is cancelled, delayed, or reduced in scope. In the case of mains renewal, the mains repairs asset health PC does not reflect an immediate impact of investment, it can be impacted by weather conditions and leakage activities and the scale of the investment we are seeking would be much greater than the ODI value making it unsuitable as a tool to protect customers. We therefore propose to use price control deliverables with commitments to protect customers.

8.2.1 Description of PCD

We commit to deliver mains renewal at the 0.17% renewal rate set within the Ofwat base models, which equates to 231 km over AMP8. We are also replacing a further 44.1 km to meet our leakage reduction performance commitment levels, as requested in our leakage enhancement claim.

For the additional funding of £74.36 million we are requesting here, we will deliver additional mains renewal at the efficient unit rate of £273.47 per metre, which equates to an extra 271.91 km of main renewed between 2025 and 2030.

If we do not deliver the level of mains renewal we have calculated as being allowed for in the base cost models, we will return all the additional funding allowed for this additional mains renewal programme to customers based on this efficient unit rate. If we do not deliver on the mains renewal programme we will return the proportion of the extra funding we are requesting in this case back to customers. For every km we do not deliver on our commitment, we will return the efficient unit rate back to customers at the end of AMP8 as per Figure 64.

We propose that the value of any returns due to customers be made through a net present value neutral adjustment to revenue limits in AMP9. We propose that the maximum value returned to customers be capped at the total value of the adjustment we are seeking. The application of this cap does not in any way limit the protection to customers interests because if it were ever reached the full adjustment would be neutral in value, that is, nothing lost or gained for customers.

FIGURE 64:1 PRICE CONTROL DELIVERABLES FOR THE ADDITIONAL MAINS RENEWAL SCHEME

Deliverable	Unit	AMP8 Total
Delivery of additional mains renewal above 0.17% annual rate funded from base allowance	km	271.91

8.2.2 Output measurement and reporting

We will deliver the water mains renewal programme in line with the risk prioritisation tool we have developed and will be improving throughout the AMP8 period. We will report on delivery of all water distribution mains renewal through the existing APR process, including gaining assurance from our APR assurers.

8.2.3 Conditions on Allowance

We will deliver the mains replacement funded within the PR24 base allowance at 0.17% per annum renewal rate, amounting to 231.12 km of mains renewed. We are committing to a further 42.70 km of renewal in Suffolk in our enhancement claim relating to our leakage reduction programme. This claim and the customer protection around it is for additional funding for mains replaced above the assumed level funded by the base models and the additional km allowed for to meet our leakage performance commitment levels.

We commit to spend all of our capital maintenance allowance in the 2025-30 period to be able to access the additional funding, and any shortfall would be deducted from this enhancement case funding.

Should we be able to achieve the lengths of mains renewal as set out in this enhancement case for less than the allowances stated then we will reinvest any available monies in further capital maintenance investments but cost overruns against these cases will be addressed through cost sharing.

We will retain a minimum asset management competency, as measured by the asset management maturity assessment (AMMA) rating across the AMP8 period of 'competent' and will also retain our ISO 55001 accreditation throughout the period to demonstrate that we are managing our assets effectively. Our latest assessment confirms we meet these requirements today. We commit to carrying out an independent assessment of AMMA in 2027-28 to confirm our rating for the purposes of this PCD, in addition to participating in any other assessments that are carried out across the sector between 2023/24 and 2027/28 and to continue to undertake our ISO 55001 accreditation via AFNOR. Should we fall below 'competent' rating, as measured using the AMMA process in place in 2023/24 or lose our ISO accreditation we will return to customers any funds for mains renewal requested in this case that are unspent at that point.

8.2.4 Assurance

We will use our APR assurers to provide annual assurance of the completed milestones and forecast of likely outturn position at 31 March 2030 for our PR29 business plan.

8.2.5 PCD Payment Rate

£273.47 per metre of mains renewed, before taking into account the impact of cost sharing rates.

8.2.6 Impact on performance commitment levels (PCLs)

We do not anticipate any material impact on performance commitment levels from the additional funding in AMP8. Our deterioration modelling has demonstrated that maintaining a rate of 0.37% mains renewals maintains relatively stable performance for bursts/mains repairs over the next 20 years. This is a long-term asset health matter and this programme is not focused on making an immediate improvement to performance metrics, but rather addressing underlying risks to asset health.

FIGURE 65: FORECAST BURST LEVELS FROM A 0.37% PER ANNUM MAINS RENEWAL PROGRAMME

Forecast performance level					
Performance Commitment	**Unit**	**2029-30**	**2034-35**	**2039-40**	**2044-45**
Mains repairs	**No. per thousand km water network**	126.37	125.57	125.63	126.00

9. ANNEX 1 – FIXED ASSET REGISTER ANALYSIS – METHOD STATEMENT

9.1. INTRODUCTION

This Appendix details the analysis carried out on the Fixed Asset Register (FAR) to provide supporting information for the Asset Health case. The output of the analysis was historic spend and estimated future spend across our process assets.

9.2. OVERVIEW

In order to better understand investment in civil process assets we wanted to profile historic investment over time and estimate future expenditure using a bottom-up process. So, we needed to identify individual civils process assets, what they cost, when they were installed and when they are likely to need to be replaced. This analysis was used to provide estimates for:

- Historic levels of capital expenditure that can be reported by the class of asset created.
- A forecast of future replacement / maintenance costs that can be reported by the same asset class structure.

The scope of this analysis includes the regulated asset base but focuses on civil structures at water and wastewater treatment works.

9.3. APPROACH

9.3.1 Choice of Data Source

The first step in the analysis was establishing the best source of current asset data. Several different options were considered in detail, but due to the new Operational Asset Register (Maximo) recently being updated and still bedding in, the financial Fixed Asset Register (FAR) was the best available source for all the assets across the business. We investigated other data sources to supplement the FAR, particularly for forecasting, including asset level GMEAV[52] analysis performed in 2012 but matching data sets at an asset level proved too challenging requiring manual[53] processes to make robust use.

[52] Gross Modern Equivalent Asset Value
[53] With tens or hundreds of thousands of asset records in each source.

9.3.2 Overview of FAR

The FAR is the live register of our asset base used in financial and regulatory reporting. It contains a record of all assets we own and operate, which includes the date at which the asset was placed in service and the financial value of the asset at the time it was created in addition to a range of classification details described in Figure 66 below. When a capital project or asset adoption is completed the project completion documentation and 'as built' drawings are analysed by the capital accountants in the FAR team and records of new assets are appended to the FAR and any records for assets disposed are removed.

FIGURE 66: FAR ASSET CLASSIFICATION DETAILS

Asset classification	Description	Example
Co.	Letter indicating it the cost/asset is appointed or non/appointed	A - Appointed
Date Placed In Service	Date asset is Placed in Service/cost incurred	1 Sep 2002
Life Yr.Mo	Financial Life of asset for depreciation	20
Column 5 (Cost)	Cost of asset when placed in service	£89,912.41
Water / Wastewater	Indicates whether the site is part of Water or Wastewater	Water
CAT1	Type of site	Water Treatment Works
CAT2	Categories of process, asset class and function	Membrane Filter
CAT3		Membrane Filter – MMC – Kiosk
CAT4		Motor Control Centre
CAT5	Asset cost type including whether it is infrastructure/non-infrastructure	Non-infrastructure Addition
GL Location	Site code	Tosson WTW
Base/Enhance	Identifies whether asset was added as part of a Base or Enhancement program	Base

This analysis used a fixed copy of the FAR taken in December 2021. The FAR records captured in the last 20 years are of high quality with all fields populated by a consistent process. However, the population of some fields, such as Base/Enhancement begins to be incomplete more than 20 years ago and there is less confidence in data quality the further back records go. Records do extend for more than a century and lack of completeness is to be expected. As part of this analysis, we have attempted to infill or correct mistakes in the key fields we required.

9.3.3 Filtering for Operational Assets

We filtered the assets in the FAR to identify lines relevant to operational assets.

The first filtering step was to remove all non-appointed assets based on the values in the "Co." column. Non-appointed assets are financed outside of the regulatory allowance and are not relevant to PR24 planning.

The second step was to filter based on Category 5; asset cost type. This filtering was applied differently for the two purposes of this analysis and the differences in approach centred around the adoptions. For all the analysis we included the core company delivered capital expenditure categories; A, M, N and R – see Figure 67 below for descriptions. For all the analysis we excluded grants and income, these are included in the FAR to ensure that asset depreciation on adopted assets is calculated correctly and not charged to customers when the company has not paid for the adopted asset.

For the purpose of establishing historic expenditure, we also exclude the value of the adopted assets, as these are not expenditures that we have made (they are offset by the grants/income). However, given that we expect that the adopted asset will need to be maintained and/or replaced in future we have included them in the analysis of forecasting future expenditure which is discussed below in Section 9.3.7.

FIGURE 67: FILTERING RESULTS

Cat 5 Value	Description	Non/ Infrastructure	Number of records	Included?
A	Infrastructure Additions (Cost)	IN	41,329	y
B	Adopted Infrastructure Assets (Cost)	IN	689	y/n
C	Grant & Contribution IFRS 15 Addition (Income)	IN	2946	n
D	Adopted Infrastructure Assets (Grant)	IN	689	n
E	Adopted Non Infrastructure Assets (Cost)	NI	13	y/n
F	Adopted Non Infrastructure Assets (Grant)	NI	13	n
G	IFRS 15 Revenue Non Infrastructure (maintenance) Income	NI	0	n
H	IFRS 15 Revenue Infrastructure (maintenance) Income	IN	0	n
I	Infrastructure Connection Charges - Infrastructure (Income)	IN	62	n
J	Infrastructure Connection Charges - Non Infrastructure (Income)	NI	402	n
L	Land (Cost)	NI	315	n
M	Infrastructure Maintenance (Cost)	IN	15,586	y
N	Non Infrastructure Addition (Cost)	NI	152,761	y
R	Refurbishment (Cost)	NI	32,483	y
T	Test Value	I/NI	0	n
V	Infrastructure or Non Infrastructure	I/NI	0	n
W	Non-Infrastructure Write Off	NI	301	n
X	IAS 16 - Expensed Costs	I/NI	0	n
Y	IAS 16 - Expensed Income	I/NI	0	n
Z	Interest – All	I/NI	4,152	n

Filtering based on both of these criteria reduced the number of FAR records from a total of 251,741 to 218,323 used in this analysis.

The final step of filtering is on the “Base/Enhance” FAR column. This field is not populated for records prior to 1997 and is increasingly populated until it reached 100% in AMP7[54]. While enhancement schemes are not relevant to estimates of historic maintenance expenditure, the cost of maintaining them is relevant to future forecasting. The lines marked enhancement are thus not filtered out, but their results are excluded from any historic costs output.

9.3.4 Inflating Assets to Current Value

The costs for each line in the FAR are based on the value/spend at the date placed into service. We thus needed to identify value of each asset in a common cost base (2022/23) so that the historic and future spend can be compared.

Inflation indices appropriate for water company assets are available but the oldest civil water assets in the FAR are from 1902. No inflation index has been reported consistently that far back so the best estimates were calculated. The datasets we have available to index costs to a common price base are shown in Figure 68 below.

FIGURE 68: DATASETS FOR INDEXING COSTS

Data set	Source	Date range	Periods	Comments
COPI Index	Office for National Statistics	Jan 2014 – Current[55]	Monthly	
COPI Index	Department for Business, Innovation & Skills	Q1 1955 –Q2 2014	Quarterly	
CPIH Index	Office for National Statistics	Jan 1988 – Current	Monthly	Overlaps available COPI data
RPI Index	Office for National Statistics	Jan 1987 – Current	Monthly	Overlaps available COPI data
RPI % change	Office for National Statistics	Jun 1948 – Current	Monthly	
Composite price index	Official Data Foundation[56]	1751 – Current	Annual (calendar year)	

Our preference is to use the Construction Output Prices Index (COPI) as it measures inflation in construction costs and is therefore more closely aligned with the capital costs contained in the FAR than measures of general inflation like the Consumer Prices Index including Housing costs (CPIH) or the Retail Prices Index (RPI). The responsibility for collecting and publishing COPI data transferred from the Department for Business, Innovation and Skills (BIS) to the Office for National Statistics (ONS) in 2014. The ONS include guidance notes in their publication for how to join these two sources to extend the range of measured COPI.

[54] In AMP6 97% of value had the base/enhance field populated, in AMP5 95%, in AMP4 and in the last 3 years of AMP3 94%. Between 1997 and 2006 population of the field is much more sparse, less than 7% in total.

[55] Typically, the latest data is reported 3 months in arrears and subject to change for a further up to 6 months.
[56] UK Inflation Calculator: GBP from 1751 to 2023. Official Inflation Data, Alioth Finance, 13 Jun 23, http://www.officialdata.co/UK-inflation

The data sets available for COPI only extend as far back as 1955; 2% of asset value in the FAR is identified as being in service prior to 1955.

The date in service recorded in the FAR is to a specific day, however the range granularity of the inflation data sets collated varies from monthly to annual. We elected to use financial year average (FYA) indexing because it simplifies the computation in the analysis marginally and the loss of precision is not significant as the outturn cost in the FAR likely represents actual spend over several months or years prior to the date in service.

Figure 69 below shows how we have synthesised a FYA inflation index set for use in this analysis.

FIGURE 69: FYA INFLATION INDEX SUMMARY

Period	Data source and methodology
2014/15 to 2022/23	ONS COPI data as reported in May 2023 update.
1955/56 to 2013/14	BIS COPI data adjusted to align with ONS COPI data through a linking factor as described in ONS guidance notes.
1949/50 to 1954/55	ONS RPI data used to calculate a FYA year-on-year change
1902/03 to 1948/49	Official Data Foundation calendar year-on-year change applied to FYA; e.g. 1940 to 1941 change applied to index from 1940/41 to 1941/42.

9.3.5 Identifying Civils Process Assets

Because the FAR is an accounting tool, none of the FAR asset identifiers give us operational asset categories such as Civil, Mechanical, Electrical etc. It was thus necessary to infer these categories from the information available, in a way that could be applied across more than 200,000 entries. As civils process assets are the focus of the analysis[57], within the civils category the assets also need to be categorised into those used for process (for example, Rapid Gravity Filter) or not (for example, Administrative Building).

We used the Category 4 values as a starting point for this categorisation. The Category 4 values are a 4 letter code which identifies the category of the asset/entry, for example TANK – Tank, LEVO - Level Monitor. There are 1314 different Category 4 codes relevant for the filtered FAR.

Our approach to categorising based on Category 4 information was as follows:

- We calculated total value of filtered assets within each Category 4 classification.
- We then ranked the Category 4 items largest to smallest based on value.

[57] Consistent with the scope of works in the water treatment works civil asset health element of this case.

CAT4	Cat 4 Description	Description Notes	Total Cost
PIPE	Pipework	PIPES||C|Tubular sections joined together to allow	2,592,905,996
UNAL	Unallocated	|||End Dated||||||||	1,113,140,836
TANK	Tank	TANKS||M|Vessel to cary a liquid or a powder - me	309,009,267
PMAN	Project Management	PROJECT OVERHEAD||OH|Work associated with the	248,665,249
STRC	Building Superstructure	BUILDING||C|That part of a building built above gro	169,893,953
CHAM	Chamber	CHAMBER||C|Any round, square or rectangular spa	161,984,941
OVER	Overhead	PROJECT OVERHEAD|||Costs which are generated d	158,112,168
DESG	Detailed Design	PROJECT OVERHEAD||DS|Stage of design of a proje	146,759,039
SOFT	Software	COMPUTER EQUIPMENT||IT|Programmes used in co	135,610,904
PUMP	Pump	PUMP||M|Device to transfer a liquid or gas by creat	130,465,020

Starting with the highest value, we used engineering judgement to place each Category 4 item in the relevant Civils, Mechanical etc category. There are >1,300 Category 4 codes, this manual review assessed 52% of these codes containing 98.6% of the value. Of those assessed codes covering 89% of value could be assigned an asset category type.

CAT4	Cat 4 Description	Total Cost	Asset Category for Using	Include?
PIPE	Pipework	2,592,905,996	Civil	Include
UNAL	Unallocated	1,113,140,836	Unspecified	Include
TANK	Tank	309,009,267	Civil	Include
PMAN	Project Management	248,665,249	Study or enabling cost - Creation cost	Proportion
STRC	Building Superstructure	169,893,953	Civil	Include
CHAM	Chamber	161,984,941	Civil	Include
OVER	Overhead	158,112,168	Study or enabling cost - Creation cost	Proportion
DESG	Detailed Design	146,759,039	Study or enabling cost - Intangible Short-Life Asset	Exclude
SOFT	Software	135,610,904	Other Equipment	Include
PUMP	Pump	130,465,020	Mechanical	Include

For Civils lines, we identified the likely percentage of process assets included. Most Category 4 items are either process (100%, e.g. Rapid Gravity Filter Tanks) or not (0% Site Fencing), but categories such as Building Superstructure are split using a percentage based on the total costs of Category 1 and Category 3 values they include. The Category 1 and 3 values give a good idea of what the assets are used for within the Category 4 definition. This categorisation and process percentage was applied to all filtered FAR lines based on their Category 4 entry.

Category 4 includes many tangible assets but also descriptions associated with study and enabling costs (for example, Site Investigation, Detailed Design, Temporary Scaffolding) as well as Project Overheads, Income, Land, Software licences and Unallocated items. Costs associated with design and construction are captured in the FAR and are assigned an average life based on a weighted average of the tangible assets resulting from the project. We excluded one-off costs (like investigations) but included costs that were likely to be repeated when the associated assets were replaced (such as design costs). The decision whether to include or exclude these values was based on whether they would be likely to be repeated if the asset was replaced.

Figure 70 below shows the total value of assets in each of the asset categories and how they were treated.

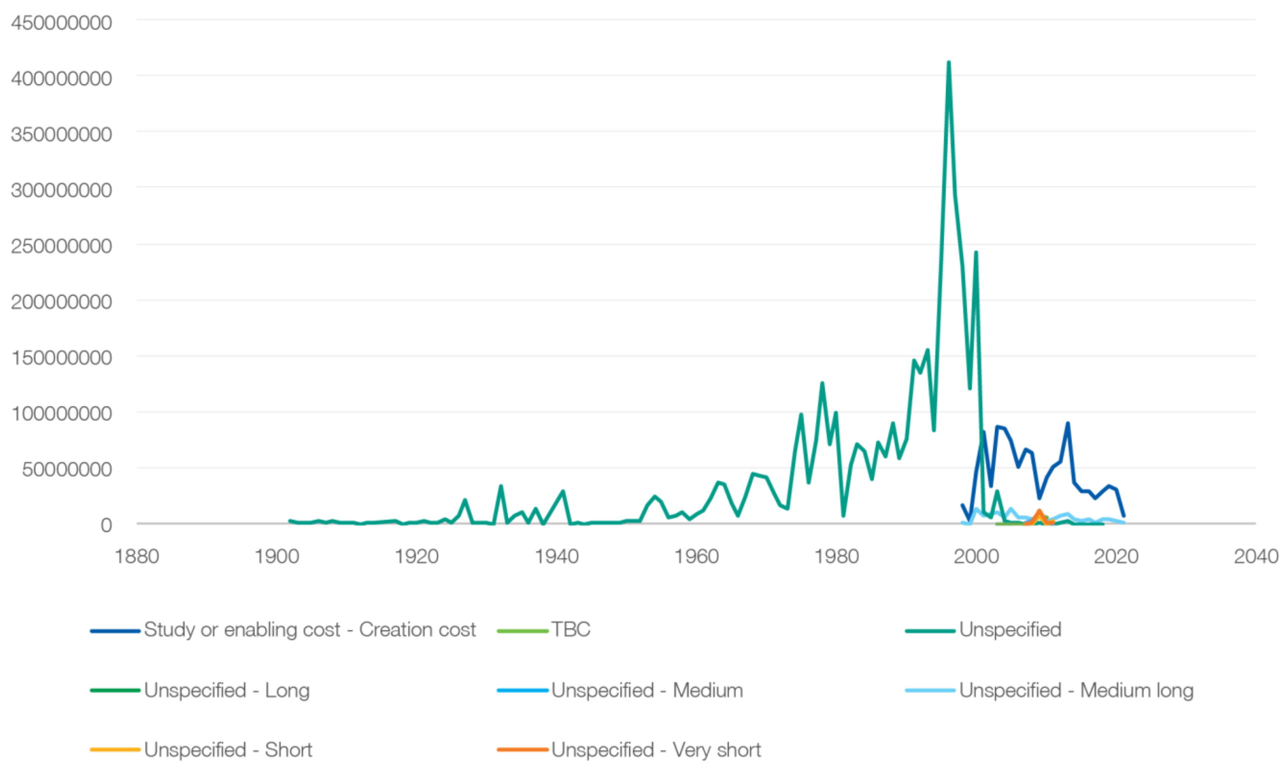
FIGURE 70: TOTAL VALUE OF ASSETS BY CATEGORY

Include/Exclude	Asset Category	Total value (£)	
Exclude	Study or enabling cost - Intangible Short-Life Asset	485,854,855	
Exclude	Operational Cost	58,090,214	
Exclude	Land	35,935,394	
	Exclude Total	**579,880,463**	5%
Include	Civil	5,505,425,178	
Include	Mechanical	488,940,976	
Include	Other Equipment	425,920,120	
Include	Electrical	318,274,061	
Include	Instrumentation	202,140,210	
Include	Telemetry	29,812,324	
	Include Total	**6,970,512,869**	55%
Proportion	Study or enabling cost - Creation cost	1,082,155,260	
Proportion	TBC	129,534,778	
Proportion	Unspecified	3,870,144,196	
Proportion	Unspecified - Medium	15,823,768	
Proportion	Unspecified - Medium long	13,325,939	
Proportion	Unspecified - Very short	13,433,104	
Proportion	Unspecified - Short	10,869,122	
Proportion	Unspecified - Long	7,560,103	
	Proportion Total	**5,142,846,270**	41%
	Grand Total	**12,693,239,602**	

There are a significant proportion of assets for which the Category 4 classification is insufficient to identify their asset category, those shown above as “Proportion”. These include the repeatable study and enabling costs. However, the majority of these (76%) are “Unspecified”, which represents all those items with a Category 4 description of “Unallocated”, “Miscellaneous” or “To be Confirmed”. There are a few other Category 4 descriptions which cannot be categorised but do contain an indication of their lifespan, primarily project commissioning overheads, these have been grouped accordingly.

Figure 71 below shows the distribution of total value in each of these categories which require proportioning. The majority of unspecified costs (99%) were incurred before 2001, so are considered a legacy issue. Other categories, including those identifying studying and enabling costs and project overheads were only used from 1998. However, it was still important to identify the civils process assets within these categories, both for understanding historic investment and estimating future maintenance requirements.

FIGURE 71: TOTAL FAR INFLATED VALUE BY YEAR BY CATEGORY



There was therefore a second step of categorising required to estimate the asset category of the individual FAR entries currently grouped into these proportion categories. We based this categorisation on the Category 1 information (type of site) and the financial asset life assigned to each entry.

Our approach to categorising based on Category 1 and Financial Life was as follows.

We identified a **higher-level grouping** for each of the Category 1 entries. These included structures, pipework and treatment.

CAT 1 Description	Grouping
Borehole	groundwater
Building	buildings
Building - DO NOT USE	buildings
Combined Sewer Overflow	structures
Communication Equipment	telemetry
Company House	buildings
Dams & Impounding Reservoirs	raw water reservoirs

For each of these Category 1 groupings we created some rules about categorisation of the individual study and enabling costs and unspecified cost lines they contain based on their FAR life. For example, for buildings it was assumed anything with less than a 10-year life is electrical (lighting etc) and anything with a greater than 10 year life is civil (structures, fences etc). The level of detail about these rules and the detail at which the individual entries were examined depended on the grouping.

Life Yr.Mo	groundwater	Buildings	structures	telemetry
0	Telemetry	Electrical	Telemetry	Telemetry
1	Telemetry	Electrical	Telemetry	Telemetry
2	Telemetry	Electrical	Telemetry	Telemetry
3	Telemetry	Electrical	Telemetry	Telemetry
4	Telemetry	Electrical	Telemetry	Telemetry
5	Instrumentation	Electrical	Instrumentation	Instrumentation
6	Instrumentation	Electrical	Instrumentation	Instrumentation
7	Instrumentation	Electrical	Instrumentation	Instrumentation
8	Instrumentation	Electrical	Instrumentation	Instrumentation
9	Instrumentation	Electrical	Instrumentation	Instrumentation
10	Electrical	Civil	Electrical	Electrical

For groupings and lives estimated as Civil, a process percentage was estimated based on the same information as above.

Grouping	Process	Non-process
groundwater	100%	0%
buildings	91%	9%
structures	100%	0%
telemetry	100%	0%
raw water reservoirs	100%	0%
pipework	100%	0%

These new rules for asset grouping of study and enabling costs and unspecified lines were applied to the applicable FAR lines to estimate their asset category and process percentage. For non-infrastructure refurbishments the FAR life was doubled before the category was applied. This doubling does not impact the historic analysis but does affect the future forecast of required maintenance / replacement, which is discussed in Section 8.3.7 below including the logic for apply this adjustment to non-infrastructure refurbishments.

CAT 1 Description	Cat 4 Description	Cat 4 Mapping	Location Description	Life Yr.M	Year	CAT1 Groupin	Groups Mapping	Civil process %
Sewage Treatment Works	1 YEAR - POH - Commissioning	Unspecified - Very short	Willington STW	1	2009	treatment	Telemetry	100%
Sewage Treatment Works	1 YEAR - POH - Commissioning	Unspecified - Very short	Long Newton STW	1	2011	treatment	Telemetry	100%
Sewage Treatment Works	1 YEAR - POH - Commissioning	Unspecified - Very short	Birtley STW	1	2009	treatment	Telemetry	100%
Sludge Treatment Plant	1 YEAR - POH - Commissioning	Unspecified - Very short	Tudhoe Mill STC	1	2009	treatment	Telemetry	100%
Sewage Treatment Works	1 YEAR - POH - Commissioning	Unspecified - Very short	Bran Sands STW	1	2009	treatment	Telemetry	100%
Sewage Treatment Works	1 YEAR - POH - Commissioning	Unspecified - Very short	Brasside STW	1	2010	treatment	Telemetry	100%

9.3.6 Grouping Assets

In order to simplify the analysis, particularly the forecasting, more than 200,000 filtered individual lines are grouped based on their characteristics resulting in 97,070 lines.

We did this as follows:

- The Year Placed into Service of each Filtered FAR line was calculated from the Date Placed into Service. These lines were then grouped based on all characteristics apart from cost, including Categories 1-5, Life, Location, and Year of Installation, giving 1 line for each unique combination.
- The cost of the items in each group were summed to give a single (uninflated) value for each grouped line.
- The appropriate civils/mechanical etc category and process percentage were selected for each grouped line, using the Category 4 mapping as the primary identifier, with Category 1/life mapping used where Category 4 was not specific enough.
- The individual cost lines were then inflated based of the combined COPI index. There is a setting to select whether all costs are included or only those specified as Civils Process (the cost is multiplied by the process percentage).
- Historic investment per year can then be plotted for any selected categories based on the inflated cost and year placed in service, specifically civils process for a given type of site (WTW, STW etc).

9.3.7 Forecasting Future Replacement

We chose a simple approach to estimating asset replacements that can be applied across all the assets. It uses the financial asset life from the FAR combined with a simple triangular asset life model to estimate the likelihood of replacement each year from 2025 to 2082. Several different options of asset replacement models and modelling were investigated but it was concluded this was the most consistent approach to give the overall picture.

Approach to forecasting replacement:

- We calculated the likelihood of first replacement from new for each possible asset life in the FAR (0-200 years) using a 50% triangular model distribution – for example, Asset life 2 years, triangular distribution min 1 year, most likely 2 years, maximum 3 years.
- These distributions were then compounded to create a likelihood of replacement from new each year for each asset life. This accounts for ongoing replacements by combining multiple triangular distributions.
- We applied these models to the appropriate lines in the grouped FAR based on their FAR asset life and current age. This gives the likelihood of replacement for each line, in each year, from 2025 to 2082.
- Where assets are life expired the historic replacement probabilities were summed and placed in 2025 giving an indication of the "backlog".

- The likelihood in each year was then multiplied by the inflated FAR cost of each group to give an estimated spend in each year from 2025 to 2082.
- These individual line items can then be summed to give total estimated future costs in each year for any category, specifically civils process for a given type of site (WTW, STW etc).

Details of individual elements of replacement forecasting:

Asset life models

We looked at multiple alternative asset life models, but the simplified financial asset life assumptions proved to be most applicable and consistent across the asset base. Inspection revealed them to be high level but not too conservative. They serve to give an overall picture of the asset base and its likely future investment requirements, which is what was required. More detailed models that take into account site specific factors would be required to give more granular results.

Triangular distributions to give an estimate of the range of possible failure ages are also a simplifying assumption, but again one that is applicable at a higher level. We carried out sensitivity analysis that looked at changing the spread of the triangular asset life distributions. The results can be seen in Figures 72 and 73 below.

FIGURE 72: ALL FILTERED ASSETS – HISTORIC AND FUTURE INVESTMENT – 50% TRIANGULAR DISTRIBUTIONS

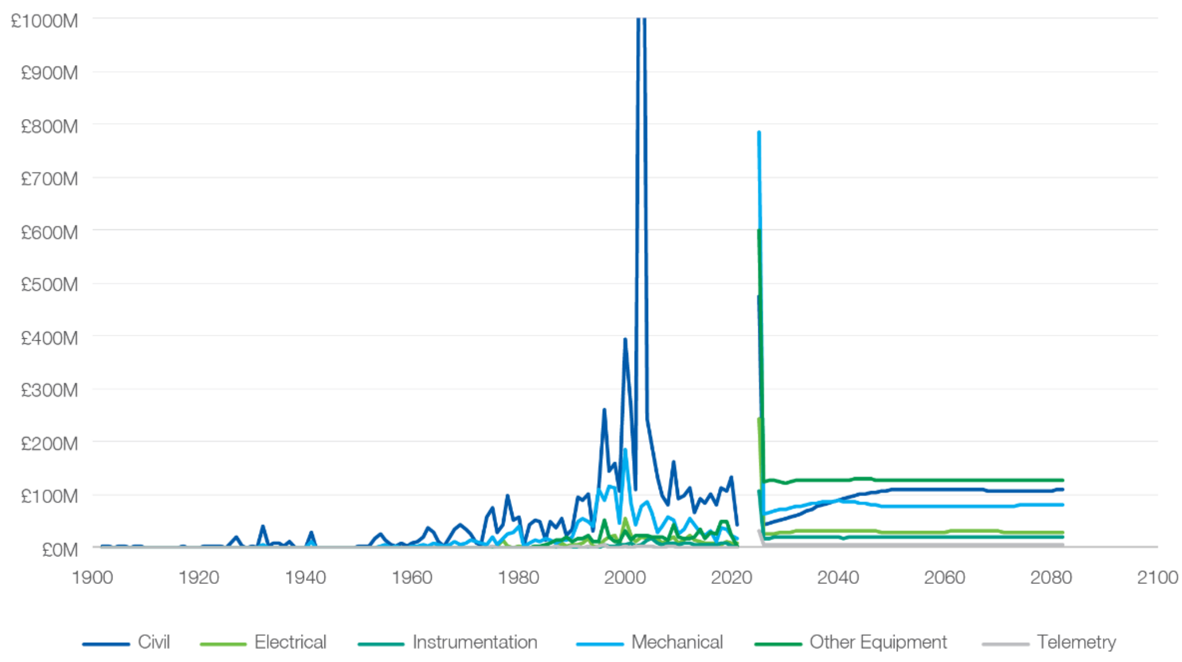
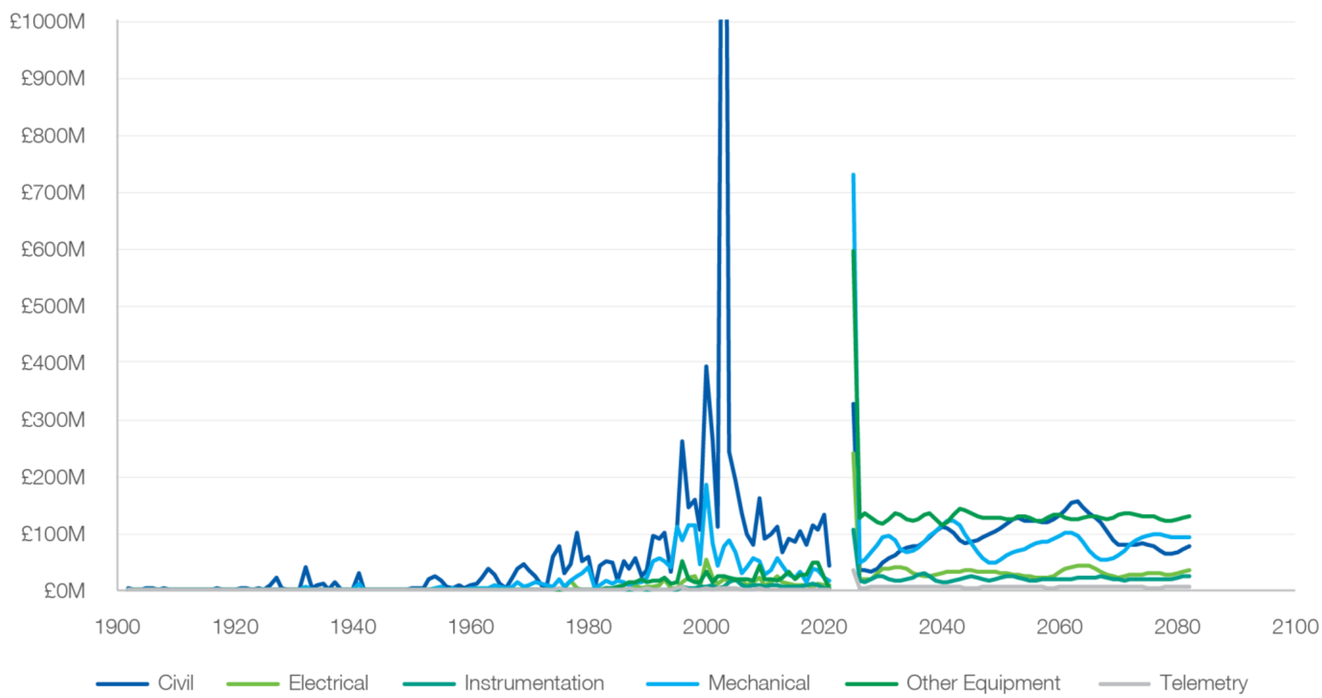


FIGURE 73: ALL FILTERED ASSETS – HISTORIC AND FUTURE INVESTMENT – 10% TRIANGULAR DISTRIBUTIONS



If a much reduced triangular distribution spread is used, the result is a very similar backlog and average steady state future requirement. The estimated investment is just more variable year on year. The reality is likely to be more complex given individual asset operating conditions, maintenance etc, and the investment choices made. It was concluded the 50% distribution better represented these realities.

Refurbishments

Refurbishments are captured in the FAR as separate lines with their own cost, but with the same categories 1-5 and location as the asset being refurbished. The asset life is a proportion of the original asset life, analysis of the FAR data suggests this is usually 50%.

In the majority of cases, these refurbishments are required to attain the asset life of the original asset. This means they will need to be repeated for any replacement asset, just offset from the replacement date. After analysing the refurbishment entries, we concluded that doubling the FAR asset life for these lines achieves this result and give a good estimation of costs and timings going forward. Therefore, all lines with a Category 5 entry of R had their lives doubled, both for forecasting and for the Category 1 / Life categorisation infill step discussed in Section 9.3.5.

Expenditure identified in CAT5 as refurbishment for non-infrastructure assets is likely to be a major servicing / overhaul. It might for example include the inspection, maintenance and replacement of bearings or impeller on a pump; this typically occurs at around the mid-point of asset life. The practice in the FAR is to depreciate the cost of this refurbishment over the remaining life of the asset - that is, around half of the life of the original asset. Using this asset life estimate for the refurbishment work unadjusted to create a forecast of maintenance / replacement cost will then imply that refurbishment is required both at the mid-point in the life of the asset but also at point of construction. We therefore double the asset life of non-infrastructure refurbishment in the estimation of future maintenance / replacement costs to ensure they align to a realistic cycle of cost.

Compound Triangular Distributions

Because the forecast of future expenditure extends beyond 2080, for shorter life assets our analysis required assets replaced in the forecast to be replaced for a second time. This necessitated calculating a compounding triangular distribution. To simplify the calculations, we created a library of calculations for every possible combination of asset life and age in the filtered and grouped FAR data set, copied the resulting library to the live analysis and then referenced the relevant section of the library.

Very short life assets

There are a number of entries in the FAR with an asset life of less than 2 years. These costs are likely to represent items considered as operational costs and therefore should not be repeated. These represent 0.2% of the total inflated costs and are considered as one-off costs that are not repeated in the forecasting step.

Years 2022-2025

In order to forecast future investment a simplifying assumption is used that between 2022 and 2025 the assets are invested in to keep them in the same condition as 2022. Therefore, the historic record stops in 2021 and the forecasting starts in 2025. This creates an implicit assumption that maintenance in the three-year window exactly offset deterioration in that same period. This assumption will be directionally true, maintenance will offset some deterioration, but whether the underlying asset condition deteriorates or improves over this period cannot be known in advance.

Cost base

All costs are set to cost base 2022/23.

10. ANNEX 2 - DETAILED CASE STUDIES OF CIVIL ASSETS

10.1. DETAILED CASE STUDIES – WTW CIVIL ASSETS

Detailed Case Study - Mosswood Derwent North WTW: Clarifiers

Mosswood WTW is located in County Durham, north of the river Derwent, serving 288,000 customers with a deployable output of 140Ml/d. The Works appears to utilise a conventional treatment process of clarification followed by filtration via Rapid Gravity Filters, disinfection and then release into the distribution network.

The clarifiers are cast in-situ, above ground reinforced concrete structure which gathers the 27 x individual clarification cells into one overall structure with intermediate distribution and collection channels. The clarifier structure has had pre-cast panels or cladding fitted to its south wall but these aside there is no protective building or other covering to mitigate the full effects of the weather.

The clarifiers were in use during the site survey so the condition of the external faces of the tanks and the distribution channels / tank tops above the water line only could be assessed.

Overall, the clarifiers are in poor condition. The Report notes numerous vertical and horizontal cracks on the exposed (non-clad) western face, with efflorescence present along construction joints but no active leaks. There is spalling and cracking in areas all along the full length of the structure's coping, particularly on the outlet channel between 5c and 4c. There are internal access corridors between / under the tanks but they are poorly lit, which is a H&S issues. Numerous leaks were observed at the construction joints resulting into standing water.

It is difficult to identify a specific cause of the observed vertical and horizontal cracks. The Report does not note any obvious level differences in the coping levels of tanks / channels or walls that have moved away from the vertical which would suggest differential settlement and hence cracking. There are numerous other possible causes e.g. localised cooling during construction, which could cause a small section of concrete to pull away from the bulk of the structure resulting in vertical cracking. The Report doesn't note the size/width of the cracks but the examples shown may not be structurally significant (but further investigation required). However, the spalling off of concrete exposing the underlying rebar indicates that water has penetrated through the concrete section and started corroding the reinforcement. This is significant and should be repaired.

The "traditional" method for repair is to decant the tank's contents; cut out the concrete around the affected area; assess how badly corroded the reinforcement is, if the steel section loss is significant then the rebar needs to be cut back also and replaced; recast the removed concrete. There may be newer methods available but this will require material specialist assessment and input. Where joint sealant has degraded, this should be replaced. It is also recommended that further structural investigations are undertaken to determine if there are any underlying causes for the cracking.

The clarifiers are integral to the treatment process and no alternative process units appear available. Due to the clustering of the clarifiers into one structure with shared collection channels a serious structural failure of one unit may affect several neighbouring tanks. Avoiding repairs will only exacerbate the deterioration of the clarifier structure potentially endangering the Works as a whole.

Detailed Case Study - Lartington WTW Clarifiers

Lartington Water Treatment Works (WTW) is located in County Durham, serving 540,377 customers with an output of 128MLD. The Works appears to utilise both upflow clarifiers and Dissolved Air Flotation (DAF) units for the initial treatment stage before filtration via RGFs. It is assumed that the majority of flow is treated by the clarifiers.

The 4 No. Clarifiers are elevated, above ground structures, constructed using post-tensioned reinforced concrete, fed by an elevated, open channel.

The Report notes that the distribution channel to each group of 2 x 2No. clarifiers appears close to hydraulic over load with very little (~50mm) freeboard present at the time of site visit. The channel itself shows signs of numerous vertical cracks which have some traces of efflorescence. In one location there is an active leak from the base of the channel. The Report also notes that the sealant at formed / construction joints along the channel appear in poor condition.

The 4 x No. Clarifiers all have similar issues but with variations to the severity. All of the clarifiers have a horizontal crack running around all or most of the tank's circumference, with signs of leakage (e.g. weeping or damp patches on the external face of the tank) and efflorescence. In some locations the steel reinforcement has been exposed and rust staining on the surrounding concrete indicates the internal rebar is corroding. Clarifier No.3 has a full height vertical crack, and from the site photographs it's also apparent that many of the vertical, formal joints created during construction are subject to efflorescence.

The horizontal crack on the clarifiers appears at approximately the same height on all tanks which appears to be coincident with a construction joint / kicker. Since this fault appears on all four of the clarifiers, it is assumed that there must have been a flaw in the construction method used. With respect to other cracks, without a full structural investigation it would be difficult to determine the cause. The Report doesn't note any obvious signs of differential settlement across the tank which may have been a root cause for vertical cracking.

The "traditional" method for repair is to decant the tank's contents; cut out the concrete around the affected area; assess how badly corroded the reinforcement is, if the steel section loss is significant then the rebar needs to be cut back also and replaced; recast the removed concrete. There may be newer methods available but this will require material specialist assessment and input. Where joint sealant has degraded, this should be replaced. It is also recommended that further structural investigations are undertaken to determine if there are any underlying causes for the cracking.

The condition of the clarifiers will continue to degrade over time if not repaired. It's unlikely that the leaks noted will self-seal and the process of corrosion of the internal reinforcement will continue to a point that the tank's structural integrity is compromised. An alternative primary treatment process (DAF) appears to be available on site but it is assumed that the DAF units were constructed to increase / augment the Work's overall treatment capacity and could not compensate for the loss of 1 or more clarifiers over time.

Detailed Case Study - Chigwell WTW: Vertical Flow Tanks

Chigwell Water Treatment Works (WTW) is located in Essex, serving 320,964 customers with an output of 90MLD. The Works appears to utilise both Rapid Gravity Filters (RGFs) and Slow Sand Filters (SSFs) for the secondary filtration stage after the initial sedimentation stage achieved via the Vertical Flow Tanks.

The 16 No. Individual Vertical Flow Tanks (VFTs) are clustered together into a large, monolithic structure, 2 rows of 4 VFTs each side of a central distribution / collection area. The tanks are semi-buried but the underground portion is substantially greater than the portion protruding above ground.

The VFTs are noted as being in poor condition. On the above ground portion of the tanks, large cracks and active leaks are reported across the structure, with them being especially prevalent on the external north wall. There is also extensive vegetation growth across the structure as a whole. Wall cracking, some leakage and efflorescence along construction joints, especially on the ceiling structure, is also observed on the underground tank portion, accessed via tunnels / corridors between the tanks. The leaks have caused concrete to spall off and expose the internal rebar.

The ceiling leakage / efflorescence is anecdotally attributed (no structural / level survey appears to have been undertaken during the site visit) to differential settlement, which may have been due to burrowing animals undermining the tanks.

As previously noted, the "traditional" method for repair is to cut out the affected concrete around the crack /leak; assess how badly corroded the reinforcement is, if the steel section loss is significant then the rebar needs to be cut back and replaced; recast the removed concrete. There may be newer methods available but this will require material specialist assessment and input. In this instance, further structural investigations would be recommended to determine if the differential settlement is continuing.

Detailed Case Study – Walpole WTW: Treated Water Storage Tank

Walpole Water Treatment Works (WTW) is located southwest of Lowestoft, Suffolk, and uses water extracted from ground boreholes which is aerated, filtered and disinfected before transfer out into the supply network.

The Treated Water Storage Tank is a 15m diameter above ground reinforced concrete tank. The tank appears to have extensive cracking and efflorescence across its surface, including a substantial horizontal crack. There is extensive leaking from these cracks, in particular in two separate areas. The tank has been repaired in the past but these repairs are now leaking and as such, the tank needs replacement.

Detailed Case Study – Broome WTW: Main Building / Filter Room

Broome Water Treatment Works (WTW) is located southeast of Norwich, Norfolk. Water is drawn from a borehole, aerated, and then filtered with pressure filters before disinfection and transfer out into the distribution system. Aside from a separate kiosk for the borehole, all the treatment processes are contained within a single main building.

The main building is graded as being in poor condition with extensive weathering to the brickwork which is also subject to long vertical cracking. The potential full extent of the structural damage is hidden by a layer of render. The roof appears to have been damaged in some significant way since scaffolding and temporary covers have been installed to try and provide shelter to the building's interior. The ceiling to the Work's Filter Room, contained within the building, has completely collapsed and is being supported by boards and scaffolding. There are large cracks to the walls, water ponding in the room despite the temporary measures and H&S is compromised (i.e. restricted access due to scaffolding, water on floor, reduced / temporary lighting).

Although further investigation may be required, it is assumed that the repairs to date have been ineffective and as a minimum the entire treatment building's roof needs to be urgently replaced. Further replacement / repair measures may be required to the building's structure.

Detailed Case Study – Bedingfield WTW: Water Tower

Bedingfield Water Treatment Water (WTW) is located in Norfolk, serving 1,987 customers with an output of 0.99MLD. Water is drawn from twin boreholes, aerated, and then filtered before disinfection and transfer out into the distribution system. There is on-site treated water storage, including a water tower.

The water tower has been assessed as being in poor condition. There are damp patches and moss growth on the underside of the tower indicating leaks. There are large cracks across columns, cross beams, and the walls of the elevated reservoir. Concrete has spalled off the tower in numerous areas, exposing reinforcing steel and there are rust stains across the structure indicating internal corrosion. The spalling is so severe that scaffolding and boarding have been erected at the tower's base to protect Operatives from falling concrete.

It's estimated that the tower has been in place since the 1950s. It can be assumed that the tower must have undergone some previous maintenance and/or repairs in the previous 60 plus years. Given that the tower is in a condition that significantly sized pieces of concrete are spalling from the structure, the tower may be beyond normal repairs and requires to be replaced.

10.2. DETAILED CASE STUDIES – STW CIVIL ASSETS

Detailed Case Study – Hexham WwTW: Trickling Filters (Brick Construction)

Hexham Wastewater Treatment Works (WWTW) is located on the north bank of the River Tyne, near the town of Hexham, servicing a population equivalent of 14,500 with a dry weather flow of 33.05l/s. The Works uses a mix of conventional treatment processes comprising preliminary treatment (inlet works), primary settlement tanks, storm storage, and then both ASP / Surface Aeration lanes and trickling filters for secondary treatment, concluded with final or humus settlement tanks.

The trickling filters are above ground, circular structures built from double leaf engineering brick with concrete coping stones, presumably supported on a cast in-situ concrete base. The trickling filters were operational, with media during the civil asset health assessment, therefore only the exteriors of the filters were assessed.

Overall, the filters are in very poor condition. Across all four of the filters there are numerous vertical and horizontal cracks running around the full perimeter of the filters. The vertical cracks are often the full height of the structure and run through the brickwork, splitting the brickwork, rather than just following the horizontal bed lines. In addition, in Filters Two and Three there is a continuous horizontal crack running completely around the perimeter through the mortar bed. In Filter Two the designed expansion joints in the walls have expanded in several places. In Filter Three, it appears there has been a failure of the wall which has bulged and moved away from the rest of the structure.

To maintain their structural integrity, all four filters have been fitted with bearing plates and two tension cables, one located at the same level as the top of the media and the second toward the filter base, which is assumed to be taking the majority of the loading. The Atkins assessment report noted that the remedial work had taken place between 10 to 15 years ago. Once the plates and cables reach the end of their design life, it is likely the filters will experience significant or total structural collapse. Accordingly, the filters were graded currently at 4b but likely to move to grade 5.

It is difficult to identify a specific cause of the observed vertical and horizontal cracking. However, this mode of cracking / tension failure of the external wall is apparently observed relatively frequently for this type of filter, with this type of construction. The base structure couldn't be viewed to determine if there had been any differential settlement.

The filters have already undergone remedial repairs to extend their operational life. It may be difficult but possible to replace the existing brackets / tensioning cables with a new set, but this would require specialist investigation. It is also possible to completely rebuild the filter walls in a sequential programme of repairs, but this assumes (a) the concrete base structures are undamaged (filters will need to be taken off-line and emptied of media to investigate) (b) there is sufficient long term spare secondary treatment capacity available within the other filters / aeration tanks to allow investigation/repairs to happen, or sufficient additional temporary treatment capacity can be brought in (c) it is cost effective to do so.

The filters are integral to the treatment process.

Detailed Case Study – Consett WwTW: Distribution Siphon Chambers A and B

Consett Wastewater Treatment Works (WWTW) is located near the River Derwent, northwest of Consett in Northumberland. The Works consists of storm storage, primary settlement, trickling filters, humus tanks, NSAF, and sludge storage tanks.

The siphon chambers, assumed to feed primary settled water to the trickling filters, are two above ground, cast in-situ circular concrete structures. They have the same outward appearances, and it is therefore assumed they were constructed at the same time. The assessment was carried out on the exterior of the structures only.

Both siphon chambers have similar defects e.g., several large vertical and horizontal cracks, a number of which are actively leaking. Of particular interest is a horizontal crack which appears to run continuously around the tank's perimeter at the same height. This defect is repeated in both tanks at approximately the same height from the ground (700mm and 750mm) which suggests a common cause, possibly a faulty construction joint or kicker.

The cracks which show signs of active leakage will inevitably lead to or accelerate the corrosion of the internal steel reinforcement and hence curtail the tank's expected 60 years design life. Repair options will depend on the frequency and severity of the cracks. The concrete around a single, severe crack, like the continuous horizontal crack could be cut back, the reinforcement cleaned of corrosion, and new concrete poured. For numerous, severe vertical/horizontal cracks it may be possible to patch the cracks internally with specialist concrete mixture or epoxy materials. Both methods of repair would require specialist material input and also process assessment regarding available treatment capacity – there are two chambers and eight trickling filters. It could be assumed that taking one chamber out of service for repairs may remove 50% of the filter capacity, which may be difficult to compensate for.

Detailed Case Study – Barkers Haugh WwTW: Trickling Filters (Pre-Cast Concrete)

Barkers Haugh Wastewater Treatment Works (WWTW) is located on the River Wear, near the city of Durham, serving a population equivalent of 35,138 with a dry weather flow of 83.81 l/s. The Works comprises storm storage, preliminary treatment / inlet works, primary settlement, trickling filters as secondary treatment, humus tanks, sludge storage tanks plus intermediate pumping stations.

The trickling filters are above ground structures comprising vertical pre-cast concrete units bolted together and set on a cast in-situ concrete base. The panels themselves are in relatively good condition with some light cracking across the surface and spalling around the edges. The concrete base could not be inspected since the filter was full of media and in use. However, at the interface between the panels and the base slab the sealant appears to have degraded and there are now leaks.

The cause of the leakage appears straight forward – the sealant between the two tank elements has come to the end of its working life and has degraded. Repair or replacement may be less straight forward requiring the filter being taken out of service and partially or wholly dismantled, with the media removed.

11. ANNEX 3 – FULL LIST OF ASSETS CATEGORISED BY PCD VALUE

11.1. INTRODUCTION

This Annex provides detail of the full list of assets identified as being in condition grade 4 and therefore included as part of our proposed AMP8 investment plan. The list is categorised by the project value grouping applied in the Price Control Deliverable. The value grouping is determined by the proportional allocation of the total programme value to each asset.

11.2. LIST OF WATER SERVICE ASSETS

PCD value group	Site	Asset
£10,000 or less	Barsham WTW	Contact Tank Valve House
	Coldfair Green WTW	Blower room
	Hanningfield WTW	GAC Contactor - overflowing sump
	Honey Hill WTW	Final effluent tank - not in tracker
	Honey Hill WTW	Meter house
	New Winning WTW	Main process building - external
	New Winning WTW	Main process building - internal
	New Winning WTW	Store cupboard southeast
	Stoneygate WTW	Main process room
£10,001 to £50,000	Barsham WTW	Fuel Store
	Barsham WTW	Pump room
	Broken Scar WTW	FBC - East
	Broken Scar WTW	Inlet Channel West
	Broome WTW	Diesel store and generator
	Broome WTW	Main building - external
	Fontburn WTW	Dump tank
	Hanningfield WTW	GAC Contractors - rebar
	Langham WTW	flow recorder house
	Langham WTW	Fuel Store
	Langham WTW	Primary filter, blower and backwash pump house
	Lartington WTW	Main Building
	New Winning WTW	Store cupboard/control room southwest
	Redgrave WTW	Filter Room
	Stoneygate WTW	Basement
	Stoneygate WTW	Booster pump room
	Stoneygate WTW	Phosphate and Hypochlorite delivery point
£50,001 to £250,000	Barsham WTW	Clarifiers
	Barsham WTW	Iron filters
	Barsham WTW	Main building
	Barsham WTW	Sludge lagoon 1
	Barsham WTW	Sludge lagoon 3
	Chigwell WTW	Vertical flow tanks
	Coldfair Green WTW	Filter structure
	Fontburn WTW	Sludge cake bays
	Hanningfield WTW	GAC Contactors - leaks
	Hanningfield WTW	Oil and Diesel Tanks
	Hanningfield WTW	Ozone Contact
	Hanningfield WTW	Ozone Dosing Room
	Hanningfield WTW	Ozone MCC Room
	Hanningfield WTW	Pulsator Clarifiers - concrete repairs

	Hanningfield WTW	Pulsator Clarifiers - open mesh flooring
	Honey Hill WTW	Clarifiers
	Honey Hill WTW	Sludge mixing and balancing tank - not in tracker
	Langford WTW	Vertical Flow Tanks (Clarifiers?)
	Langham WTW	High lift PS
	Lartington WTW	Clarifier 1
	Lartington WTW	Clarifier 2
	Lartington WTW	Clarifier 3
	Lartington WTW	Clarifier 4
	Lartington WTW	Filter Room
	Layer WTW	Chlorine Drum lifting beam
	Layer WTW	Chlorine Drum Store Roof
	Lumley WTW	Clarifiers
	North Dalton WTW	Well 2 with Gantry
	North Dalton WTW	Well 3 with Gantry
	Ormesby WTW	Clarifiers
	Ormesby WTW	Filter Building
	Ormesby WTW	Sand Filter 1-3 Access Road
	Ormesby WTW	Sand Filter 1-3 Access Road - Walls
	Stoneygate WTW	Main Building - exterior
	Walpole WTW	Aeration tank
	Walpole WTW	Backwash tank
	Walpole WTW	Treated Water Storage Tank
£250,001 to £1,000,00011	Barsham WTW	Backwash tanks
	Bedingfield WTW	Aerator tank
	Bedingfield WTW	Water Tower
	Benhall WTW	Aeration tanks
	Coldfair Green WTW	Aerators
	Eye WTW	Water Tower
	Hanningfield WTW	Pulsator Clarifiers
	Holton WTW	Aerator
	Layer WTW	Chlorine Injection Building
	Mendlesham WTW	Aerator
	Mosswood WTW	Phosphoric Acid Bund
	Ormesby WTW	GAC
	Ormesby WTW	Slow Sand Filter 4
	Ormesby WTW	Slow Sand Filter 5
	Ormesby WTW	Slow Sand Filter 6
£1,000,001 to £2,500,000	Mosswood WTW	Clarifiers
£2,500,001 to £5,000,000	No water assets in this group	No water assets in this group
£5,000,001 to £7,500,000	Langford WTW	East Raw Water Reservoir
	Langford WTW	West Raw Water Reservoir
More than £7,500,000	No water assets in this group	No water assets in this group

11.3. LIST OF WASTEWATER SERVICE ASSETS

PCD value group	Site	Asset
£10,000 or less	AYCLIFFE STW	TF Distribution chamber 3-4
	BARTON STW	Trickling Filter No.1
	BROWNEY STW	ASP feed chamber
	EGGLESTON STW	Siphon chamber
	FALSTONE STW	Fencing
	FISHBURN STW	Filter distribution chamber
	FROSTERLEY STW	Sludge tank 1
	GREATHAM STW	Sludge holding tank
	KELLOE STW	FE circic PS
	LEAMSIDE (WEST RAINTON) STW	Humus return PS - not in tracker
	LYNEMOUTH STW	Pumping station building - not in tracker
	SCOTS GAP STW	Humus Return Pump House
	SHERBURN HOUSE STW	Siphon chamber
	SKINNINGROVE STW	Inlet works chamber
£10,0001 to £50,000	ALDIN GRANGE NTH (BEARPARK)	Retaining wall
	AYCLIFFE STW	Inlet Works - northern inlet
	BARKERS HAUGH STW	Storm tank 2
	BARKERS HAUGH STW	Tertiary TF 1
	BELMONT STW	Ferric storage tank
	BELMONT STW	PST 4
	BERWICK STW	Digested sludge tank west
	BERWICK STW	Digester sludge tank east
	BERWICK STW	PST Distribution Chamber
	BERWICK STW	Settled sludge chamber
	BILLINGHAM STW	Storm Tank 1
	BIRTLEY STW	Inlet Works Chamber / reed bed
	BIRTLEY STW	PST Distribution Chamber
	BISHOP MIDDLEHAM STW	Inlet / humus pumping building
	BISHOP MIDDLEHAM STW	PST
	BISHOPTON STW	Inlet Structure
	BOLAM STW	Humus desludge pumping station
	BOLAM STW	Inlet works
	Bran Sands STW	Raw sludge anti-foam kiosk
	Bran Sands STW	Raw water booster pumps & break tank
	Bran Sands STW	RSTC Phase 1 building
	Bran Sands STW	SBCO Reception Tank
	Bran Sands STW	SBCO Tank 1
	Bran Sands STW	Site services north building
	BROWNEY STW	RAS/SAS pumping station
	CARLTON & REDMARSHALL STW	Abandoned Sludge Beds
	CARLTON IN CLEVELAND STW	Sludge Recirculation Building
	COCKFIELD STW	Retaining wall
	CONSETT STW	PST 1
	CONSETT STW	PST 2
	CONSETT STW	Screw pump station
	CONSETT STW	Siphon distribution chamber 1
	CONSETT STW	Siphon distribution chamber 2
	CONSETT STW	Storm Tank 2

	CONSETT STW	Storm Tank 3
	CONSETT STW	Storm tank 4
	CRAMLINGTON STW	Sludge holding tank
	CROOKHALL STW	Storm Tank 1
	CROOKHALL STW	Storm Tank 2
	CROOKHALL STW	Storm Tank 3
	CROOKHALL STW	Storm tank 4
	CROOKHAM STW	Humus sludge pumping station
	CROOKHAM STW	MCC Kiosk
	EDMUNDBYERS STW	Valve chamber
	EGGLESTON STW	PST
	EMBLETON STW	PST
	EPPLEBY STW	Site Cabin
	FALSTONE STW	Footpath
	FALSTONE STW	PST
	FISHBURN STW	Pump chamber
	GAINFORD STW	PST 1
	GREATHAM STW	Storm tanks
	HUTTON RUDBY STW	Trickling filter distribution chamber
	LEAMSIDE (WEST RAINTON) STW	Skip building
	LOCKHAUGH STW	Storm Tank 1
	LOCKHAUGH STW	Storm Tank 2
	LOCKHAUGH STW	Storm Tank 3
	LOCKHAUGH STW	Storm tank 4
	LOW WADSWORTH STW	Trickling filter 1-4 siphon chamber
	LOW WORSALL STW	Distribution chamber
	LOW WORSALL STW	PST1
	LYNEMOUTH STW	PST 1
	MARSKE STW	SBR 4
	NEWBY STW	Sludge Tank
	PARK VILLAGE STW	Inlet chamber
	PITTINGTON STW	Storm Tank 1
	PITTINGTON STW	Storm Tank 2
	PITY ME STW	Primary Tanks
	ROTHBURY STW	Storm Tank 1
	ROTHBURY STW	Storm tank 2 - not in tracker
	SADBERGE STW	Macerator
	SEATON CAREW STW	Lamela plant - internal building
	STAMFORDHAM STW	Trickling Filters
	STOKESLEY STW	Inlet works
	WHALTON STW	Distribution chamber
	WHITTINGHAM STW	Trickling Filter
	WILLINGTON STW	Distribution Chamber for TF's 1 - 4
	WILLINGTON STW	Inlet Works
	WINDLESTONE STW	Storm Tank 3
£50,001 to £250,000	ALDIN GRANGE NTH (BEARPARK)	Humus tanks (steel)
	BERWICK STW	Inlet Works
	BILLINGHAM STW	Storm Tank 3
	BIRTLEY STW	Sludge Tank
	BISHOP MIDDLEHAM STW	Trickling media filter 1
	BISHOP MIDDLEHAM STW	Trickling media filter 2
	BLYTH STW	Storm Tank 1

	BLYTH STW	Storm Tank 2
	Bran Sands STW	SAS Tank 1
	Bran Sands STW	SAS Tank 2
	Bran Sands STW	Sludge digester 1
	Bran Sands STW	Sludge digester 2
	Bran Sands STW	Sludge digester 3
	Bran Sands STW	Sludge storage area bund
	Bran Sands STW	TAS Storage Tank 2
	CAMBOIS STW	Screenings building
	CARLTON & REDMARSHALL STW	Site Access Road
	COALBURNS STW	PSTs
	COCKFIELD STW	PST tank 1
	COCKFIELD STW	PST tank 2
	CONSETT STW	Detritor area
	CONSETT STW	Storm Tank 1
	CRAMLINGTON STW	Digested sludge tank 2
	DIPTON STW	Storm Tanks 2
	EAST WOODBURN STW	Covered PST
	EGGLESTON STW	Retaining wall
	EGGLESTON STW	Site building
	EGGLESTON STW	Sludge drying beds
	FALSTONE STW	Humus tank
	FROSTERLEY STW	Trickling media filter
	GAINFORD STW	PST 2
	GAINFORD STW	Trickling filter 1
	GAINFORD STW	Trickling filter 2
	GREATHAM STW	Humus tank 1
	GREATHAM STW	PST 1
	GREATHAM STW	PST 2
	GUNNERTON STW	Humus tank
	HEDDON HALL STW	PST
	HUTTON RUDBY STW	PSTs
	INGLEBY GREENHOW STW	Sludge tanks
	INGOE STW	Inlet and PST
	LOW WORSALL STW	Sludge Tank
	LOW WORSALL STW	Trickling filter 1
	LOW WORSALL STW	Trickling filter 2
	MITFORD STW	Trickling Filters
	PITTINGTON STW	PST1
	PITTINGTON STW	PST2
	PITTINGTON STW	PST3
	PITTINGTON STW	PST4
	ROTHBURY STW	PST4
	SCOTS GAP STW	Trickling Filters
	SEDGELETCH STW	ASP Tanks
	SEDGELETCH STW	Storm Tanks
	STONEHAUGH STW	PST
	TRIMDON STW	Trickling filter distribution chamber
	WARK STW	Sludge holding tanks
£250,001 to £1,000,000	ALDIN GRANGE NTH (BEARPARK)	Trickling filters
	Bran Sands STW	Sludge holding tank 5
	Bran Sands STW	Sludge holding tank 6

	Bran Sands STW	Sludge holding tank 7
	GREAT AYTON STW	4B - Northern Trickling Filter
	HEXHAM STW	Trickling filters Distribution Chamber
	INGOE STW	Trickling Filter
	LANGLEY STW	Trickling Filter
	LEAMSIDE (WEST RAINTON) STW	Trickling filter 1
	LEAMSIDE (WEST RAINTON) STW	Trickling filter 2
	LONGBYRE STW	Trickling Filter
	MIDDLETON-IN-TEESDALE STW	Sludge Holding Tanks
	PARK VILLAGE STW	Trickling Filter
	PITY ME STW	Trickling filters
	SADBERGE STW	Trickling filters
	TRIMDON STW	Trickling filter 3
	WARK STW	Inlet works & PST's
	WILLINGTON STW	Sludge Holding Tanks 1 and 2
£1,000,001 to £2,500,000	BERWICK HILL STW	Trickling Filter
	BERWICK STW	PST North East
	BERWICK STW	PST South East
	BERWICK STW	PST South West
	BIRTLEY STW	PST 1-4
	Bran Sands STW	ASP train A cell 1
	Bran Sands STW	ASP train A cell 2
	CARLTON & REDMARSHALL STW	Trickling Filter 1, 2 and 3
	CRAMLINGTON STW	Generator
	HOLMSIDE STW	RBC
	SEDGELETCH STW	Inlet Works (channel)
	SEDGELETCH STW	PST Tanks
	WILLINGTON STW	PST 1 and 2
£2,500,001 to £5,000,000	BIRTLEY STW	Trickling Filters 3 - 4
	WASHINGTON STW	Storm Tanks
	WILLINGTON STW	Trickling Filters 7 - 8
£5,000,001 to £7,500,000	Bran Sands STW	PTA Aeration Tank
	WASHINGTON STW	PST 1-4
More than £7,500,000	BARKERS HAUGH STW	Secondary TF1 & 2
	BIRTLEY STW	Trickling Filters 5 - 10
	EAST TANFIELD STW	Trickling filters 1 - 4
	HEXHAM STW	Trickling filters 1 - 4

12. ANNEX 4 – LIST OF CIVIL STRUCTURES IN CONDITION GRADE 4 OR 5

FIGURE 74 OVERVIEW OF WTW KEY ISSUES

Name of works	Region	Population served	Number of assets	Number of assets in CG 4 or 5	Description of key issues
Fontburn WTW	Northumberland	150,000	35	2	Dump Tank (4a) - Brick and Concrete structure. Some vertical cracking and staining but still assumed watertight. Sludge Cake Bays (4b) - Brick and Concrete structure. Cracking and spalling of brickwork. Some damage to structure from machines. Concrete coping subject to cracking and spalling exposing the aggregate.
Gunnerton WTW	Northumberland	33,840	37	1	Caustic Soda Dosing Room (4a) - Floor coating damaged plus water ingress has caused part of the ceiling to collapse damaging dosing equipment.
Warkworth WTW	Northumberland	117,600	23	1	Alum Building (4b) - Extensive cracking through brickwork and building has been previously condemned.
Dalton WTW*	Central	25,920	4	1	Main Building Internal (4a) - Extensive cracking to brick structure including walls, window frames and lintels. Evidence of water ingress (staining) through brickwork. Some corrosion to one of the internal steel support columns.
Honey Hill WTW	Central	N/A	30	5	Rapid Gravity Filter Gallery (4a) - Cracks through concrete structure approximately at tank joint locations. Mould growth and staining. Clarifiers (4b) - Cracking along underside of tanks with possible leakage and moss/mould growth. Meter House (4a) - Crack damage to brick and mortar. Damp internally suggesting leaking roof or ingress through walls. Sludge Mixing / Balance Tank (4a) - Columns supporting equipment / walkways in poor condition. Final Effluent Tank (4a) - Damp patch on GRP tank indicating potential leak.
Lumley WTW	Central	N/A [45MLD]	19	1	Clarifiers (Below Ground) (4a) - Cracking to external faces, especially prevalent to two units where there is visible surface dampness (No.6) and even standing water in the access tunnels (No.2).
Mosswood WTW	Central	288,000	33	2	Phosphoric Acid Bund (4a) - Concrete bund floor has delaminated and degraded in large areas. Water ingress from adjacent wall pipe penetrations. Clarifiers (4b) - Ageing concrete structures with spalling and cracking of the concrete along the tank coping and some outlet channels. Although external surfaces are covered by pre-cast panels, one external wall is visible, and which shows numerous vertical and horizontal cracking and patches of efflorescence. Access beneath clarifiers indicated degraded joint sealant and leaking construction joints leaving standing water in the corridors. Unlit access which is a potential H&S hazard.
New Winning WTW	Central	N/A	5	4	Main Process Building (External) (4b) - Vertical cracking through all external brick walls, some of which are actively monitored. Vegetation growth and further cracking toward building base. Main Process Building (Internal) (4a) - Some signs of dampness and efflorescence in the brickwork. Control Room / Store Southwest (4a) - Water ingress through hole in roof. Store Southeast (4a) - Water ingress through hole in roof.
North Dalton WTW	Central	N/A	13	2	Well 2 & 3 Gantry (4a) - Stell pump lifting gantry subject to significant corrosion across whole structure. The rusting has been enough to reduce the thickness of some structural members and continual monitoring required. Old Building (4a) - Cracking to concrete base slab. Weather damage to external architectural features e.g. windowpanes, doors, guttering.
Stoneygate WTW	Central	17,280	8	5	Phosphate & Hypochlorite Delivery Point (4b) - Several long horizontal cracks through walls plus hole in roof. Main Building Exterior (4b) - Large vertical cracks across building's brick exterior, some previously repaired but many still requiring action. Vegetation growth below the roof line. Entrance steps closed as H&S risk due to damage and uneven surfaces. Booster Pump Room (4b) - Several large cracks through brickwork walls. Evidence of water penetration.

					Main Process Room (4b) - Possible differential movement to overall structure. Crack to concrete floor across its entire width. Extremely large vertical crack through brick-and-mortar beds above entrance door. Signs of general water penetration. Basement (4b) - Numerous extensive cracks to brick basement structure indicting continued movement. Some spalling of concrete to roof concrete exposing rebar. Damp and mould present.
Broken Scar WTW	Tees	540,377	41	2	Feed Channel 1 from Reservoir (4a) - Extensive concrete spalling of elevated structure exposing reinforcement. Sealant at joints has deteriorated and has pulled away from the structure. Flat Bottom Clarifier East (4a) - Cracking and sealant degradation / separation at formed joints. In one location there is an active leak through a joint suggesting a failure of the internal water bar.
Lartington WTW	Tees	540,377	43	6	Basement Area (4a) - Leakage from pipe penetrations / incomplete pipe boxouts (i.e., open holes) resulting in significant standing water in access corridors. Some open box outs have exposed rebar within them which is corroding – this could spread out further to the wider structure. Clarifier 1 (4b) - Horizontal crack around entire tank circumference at construction joint / kicker level. Active leakage and efflorescence from the crack. Rebar exposed at certain sections. Clarifier 2 (4b) - Horizontal crack around entire tank circumference at construction joint / kicker level. Active leakage and efflorescence from the crack. Clarifier 3 (4b) - Horizontal crack around entire tank circumference at construction joint / kicker level. Efflorescence and staining around the crack. Concrete spalling in places with exposed rebar. Clarifier 4 (4b) - Horizontal crack around entire tank circumference at construction joint / kicker level. Active leakage and efflorescence from the crack. Rebar exposed at certain sections. Filter Room (4b) - Flat roof which appears to be leaking resulting in loose plaster and flaking paint.
Wear Valley WTW*	Tees	N/A	25	2	Lime Silo Room (4a) - Roof leaks and pooling water Lamella Basement (4a) - Visible leakage through roof, possibly through construction joints since rust staining visible.
Chigwell WTW	Essex	320,964	29	1	Vertical Flow Tanks (4b) - Extensive cracking and active leakage in all walls plus spalling to internal roof exposing rebar. Efflorescence along some of the tank joints indicative of historic differential movement. Suspicion that tanks have been undermined by animal activity.
Hanningfield WTW	Essex	517,567	35	6	Ozone MCC room (5) – cracks and leaks in flat roof Ozone dosing room (4b) – water ingress and concrete spalling Ozone contact tanks and gallery (4a) - potential failure of an internal water bar in contact tanks causing leakage GAC Contactors (4b)- cracks and active leaks to the contact tank walls, plus other leaks across the structure Pulsator Clarifiers (4b) - surface cracks with signs of active leakage, active leakage at numerous pipe penetration locations Oil and Diesel Store (4b) – Leaks and concrete separation
Langford WTW	Essex	443,402	35	6	West Raw Water Reservoir (5) - At least one significant leak resulting in large volume of standing water next to the reservoir. Full drain down required to locate defect which may be hampered by the poor condition of the division wall. Significant horizontal and vertical cracking observed in other walls. East Raw Water Reservoir (4b) - Poor condition. South wall again has significant vertical and horizontal cracking which are actively leaking i.e. water observed flowing from cracks. Horizontal crack follows construction joint. Sludge Area / Hardstanding (4b) - Standing water collecting from west raw water reservoir leak. During poorest conditions, Operatives have to wade through water – obvious H&S risk. Sludge Building (4b) - Interior of building in poor condition. Water ingress / standing water through leaking service penetrations. Spalling to underside of concrete floor. MCert Flow Meter Chamber (4a) - Channel is being overtopped therefore giving inaccurate flow meter readings. Vertical Flow Tanks (4a) - Vertical cracking through link corridor brickwork suggestive of differential settlement. Service penetrations which have not been sealed. Active leaks from filter feed channels.
Langham WTW	Essex	117,842	26	4	High Lift PS Building (4b) - Leaks through RC roof, spalling of concrete in other areas exposing rebar.

					Primary Filter / Blower / Backwash Building (4a) - Spalling of concrete from external walls, surface cracking. Rust staining from pipework. SSF Flow Recorder House (4a) - Large ceiling cracks and extensive efflorescence. Fuel Store (4b) - Concrete bund around tanks extensively cracked with concrete spalling and vegetation growth.
Layer WTW	Essex	353,530	19	3	Chlorine Drum Store (4b) - Brick building with concrete roof – cracking, spalling and exposed rebar internally. The drum lifting beams twisted and out of alignment, fouling doors. Chlorine Injection House (5) - Significant settlement to rear of this small building causing extensive cracking through blockwork / concrete foundation slab. Treated Water PS (4a) - (Small proportion of building used; repurposed as storage). Multiple flat roofs with cracking, deterioration to coatings, water ingress, staining and rusting. Standing water in some areas; corrosion and heavy wear to chequer plate flooring.
Barsham River WTR	Suffolk	87,876	38	9	Pump Room (4a) - Historic (?) water ingress through roof and roof/wall interface causing staining. Iron Filters (4b) - Horizontal cracking full length of tanks with active leaks. Corroded pipework. Backwash Tanks (4a) - Cracking to external RC surface, staining and rust patches indicating rebar corrosion. Roof not draining properly. Fuel Store (4b) - Wear / Damage confined to timber components of building. Minor damage to adjacent retaining wall. Contact Tank Valve House (4b) - Buried building with visible dam patches – probably ground water infiltration rather than tank leakage. Clarifiers (4a) - Clarifiers themselves in reasonable condition but associated building appears to be suffering from water ingress (flat roof) resulting in cracking to ceiling. Sludge Lagoon 1 (4b) - Internal leak. Sludge Lagoon 2 (4a) No safe way of emptying solids. Sludge Lagoon 3 (4a) - Localised cracking allowing water to escape to surrounding area. Penstocks jammed open. No safe way of emptying solids.
Bedingfield WTR	Suffolk	1,987	17	2	Aerator Tank (4a) - Steel tank, corroded, active leaks in places. Water Tower (4b) - Large cracks and concrete spalling across the tower structure affecting columns, beams, walls, plus stains and exposed rebar. Scaffolding in place to protect operatives from falling concrete – obvious H&S risk.
Benhall WTR	Suffolk	17,308	28	1	Aeration Tanks (4b) - Circular steel tanks in poor condition with exterior rust signs and indication of leaks at the tank tops.
Broome WTR	Suffolk	N/A	10	3	Main Building (4b) - Significant external weathering and cracking. Roof would appear to be in poor condition since scaffolding / tarpaulins put in place to provide shelter plus partial ceiling collapse. Diesel Fuel Store and Generator (4a) - Generator housing is external steel container, subject to extensive corrosion to sides/roof. Filter Room (5) - Ceiling has collapsed and required scaffolding to support it. Large wall cracks and water ponding on floor. Restricted access and temporary lighting only. H&S hazard.
Coldfair Green WTR	Suffolk	9,994	17	6	Air Blower Room (4a) - Concrete walls with cracking and active leak. Damp and efflorescence. Aerator (4a) - Average overall condition but leaking hole in one side. Water actively leaking and extensive moss building up Roof air vents blocked. Filters 1 to 4 (4a) - Structure in poor condition with vertical cracks, localised spalling along the cracks, and active leaks in places. Pipe penetrations have been poorly installed. Security mesh is corroding.
Eye WTR	Suffolk	1,548	13	1	Water Tower (4a) - Supporting beams and underside of tank in poor condition with exposed rebar, damp patches, staining, and efflorescence. Spalling concrete may be a H&S risk to operatives.
Holton WTR	Suffolk	N/A	8	2	Reservoir Tank (4a) - Signs of historic leakage, current leak likely due to roof drainage rather than cracks. Aerator (4b) - Steel tank in poor condition with visible leakage at top of tank. Aerator tank surrounded by scaffolding to prevent entry of birds.
Lound WTR	Suffolk	47,342	34	2	Slow Sand Filter C (4a) - Noticeable leakage – requires further monitoring. Paterson Rapid Filtration Plant (4a) - Numerous cracks on the walls plus some areas of efflorescence. Signs of previous water ingress from flat roof.

Mendlesham WTR	Suffolk	1,924	10	1	Aerator (4a) - Steel tank in poor condition. Weathered, active leakage indicated by corrosion, pipe fittings also corroded.
Ormesby WTR	Suffolk	104,568	28	8	Filter Building (4a) - Flat roof with significant standing water. Transverse cracking to underside of roof / ceiling indication moisture penetration. Deflection of one end of roof noted. Slow Sand Filter No.6 (4b) - Signs of spalling to internal walls / beams. Possible leakage indicated by surrounding areas being wet. Slow Sand Filter No.5 (4b) - Significant standing water to one side of filter, likely to have leaked from filter. Slow Sand Filter No.4 (4b) - Spalling concrete to visible areas. Boggy / wet ground plus standing water to side of filter indicating active leak. Sand Filter Access Road (4b) - Elevated Road supported by retaining wall now showing signs of failure resulting in movement / poor road quality. RGF Building (4b) - Building interior showing sign of wear / damp. Crack monitors installed in certain locations to base cracks. Clarifier Gallery (4b) - Numerous active leaks from clarifiers, water seen running down walls from cracks or failed joints. Concrete has spalled off at certain locations exposing rebar. Wash Water Recovery Tank (4b) - Brick structure in poor condition. One wall bowed / out of vertical alignment another wall observed with numerous cracks.
Redgrave WTR	Suffolk	7,236	16	1	Main Treatment Building – Filter Room (4a) - Significant crack in roof in one area. Historic water damage not made good.
Walpole WTR	Suffolk	N/A	17	3	Aeration Tanks (4b) - Weathered steel tanks. Primary Filter Backwash Tank (4b) - Mineral deposition at base of tank potentially indicating leakage. Further investigation needed. Treated Water Storage Tank (4a) - Concrete spalling and active leakage in form of wet exterior wall. Past repairs appear to be where leaks are occurring.

FIGURE 75: OVERVIEW OF WWTW KEY ISSUES

Name of Works	Region	Population served	Number of assets	Number of assets in CG 4 or 5	Description of key issues
Aldin Grange WWTW	Tees	2,016	9	3	Secondary Temporary Humus Tanks (4a) - There are two sets of humus tanks, one set of which are steel tanks, which although classed as "temporary" have apparently been in operation for 15years. The upgrade of the humus tanks is supposed to be part of a project which was to start in 2022. The steel tanks are in poor condition, being corroded across their surfaces, and prone to leaking. Operations staff noted that these tanks do not add anything to the treatment process due to their size and the inability to de-sludge them effectively. Percolating Filters No. 1 / No. 2 / No. 3 / No. 4 (4b) - The four filters have been assessed as all having the same condition. The brickwork across the four filters is in very poor condition with frost damage, vegetation growth, and active leaks. and been classified as being in very poor condition. The northern side of the filters are above ground, and here it is noted that the brick walls appear to be bulging which may indicate a structural failure. Retaining Wall [Civil] (4b) - The brick retaining wall is assessed to be in poor condition. It's showing signs of frost damage and appears to be overturning/falling in several places.
Allenheads WWTW	Tees	63	5	1	Secondary Clarification Humus Tanks (4b) - The humus tank is a buried concrete structure that appears to be in reasonable condition. However, the covers are constructed from wooden frames with wire mesh infill and aren't suitable for pedestrian or vehicle loading. There are no warning signs, and the covers aren't about barriered off.
Aycliffe WWTW	Tees	61,502	56	2	Inlet Works [Northern] (4a) - The concrete channel is in general good condition with some visible cracking, but the internal joints appear in fair condition. However, as the channel enters the WwTW site it spans over a watercourse (Howden Beck) and there is an active leak from a wall & base joint allowing raw wastewater to contaminate the ground water. Distribution Chamber for Filters No. 3 & No. 4 (4a) - The concrete above ground structure is in generally good condition but there is a penetration/hole in the eastern face that's actively leaking and potentially contaminating the surrounding ground.
Barkers Haugh WWTW	Tees	35,138	48	4	Storm Tank No. 2a (4a) - The tanks are constructed from concrete with internal steel supports, which are in good condition. The base slab is cracked at numerous points along the full length of the tank plus several other vertical cracks in the external and dividing walls. There is a crack to an external wall at one corner which is actively leaking. The crack / leak may be due to waterbar failure. Secondary Trickling Filter No. 1 (4b) - The filters are an above ground filter structure formed from pre-cast concrete panels. The panels are in relatively good condition having light surface cracking and localised spalling only. The issue is the junction between the pre-cast panels and the base slab where several leaks are noted. The outlet chamber is also leaking where it joins the main structure. Secondary Trickling Filter No. 2 (4b) - The filters are an above ground filter structure formed from pre-cast concrete panels. The panels are in relatively good condition having light surface cracking and localised spalling only. The joints between the panels are in relatively good condition with no visible leakage. The issue again is the junction between the pre-cost panels and the base slab where several leaks are noted. Tertiary Trickling Filter No. 1 (4b) - The filters are an above ground structure formed from pre-cast concrete panels on a concrete base. The outlet chamber appears defective with the ground at the location saturated and a noticeable flow of water coming from the joint with the main structure. The filter arm is also defective, spraying over the edge of the structure leading to excessive staining of the outside face.
Barton WWTW	Tees	768	12	1	Secondary Trickling Filter No. 1 (4a) - An above ground brick structure assessed to be in average to poor condition. Minor efflorescence has built up on the brickwork and there is one active leak from the mortar bed on the west side.
Belmont WWTW	Tees	10,181	28	3	Primary Settlement Tank No. 4 (4b) - A semi-buried concrete tank with several vertical cracks and associated spalling to the external surface. The spalling has exposed the reinforcement which is showing signs of corrosion.

					Ferric Storage Tank (4b) - The tank consists of a polypropylene tank on a concrete base. The tank was installed into 2003 and has a design life of 20 years. There is minor weathering to the external surface, but no other problem is noted. Ferric Tank Bund (4b) - A graded concrete area with integrated sleeping policemen and drains to form a containment area. There was indication that a 3-way valve was installed to allow differentiation between rainwater and ferric. In addition, the concrete area is missing some of its joint meaning ferric can leak into the ground.
Berwick WWTW	Northumberland	16,770	27	8	Inlet Works (4a) - An elevated cat in-situ concrete structure assessed to be in average to poor condition. There are several instances of cracks which are leaking, particularly in the inlet and outlet chambers. Concrete spalling has occurred at several locations exposing the rebar which is corroding. There are also instances of discoloured surface staining indicating water penetration through the structure and corrosion of the rebar within. There is also an internal rendered brick chamber which is in poor condition with the concrete render spalling off in places, as well as degradation of the brickwork. PST Distribution Chamber (4a) - An above ground, circular, cast in-situ structure in poor condition. There are several hairline cracks with damp patches and staining indicative of leakage. The chamber's cope appears to have badly spalled and degraded in places with vegetation growing in several places. The walkway supports have spalled too, exposing the rebar. Settled Sludge Tank (4a) - A rectangular concrete structure. There are cracks / voids at ground level that can be seen externally. These cracks are actively leaking. Digested Sludge Tank East (4a) - A glass coated steel tank on a concrete base. The tank is in generally good condition except ongoing active leakage around the manway / access point and a joint. Digested Sludge Tank West (4a) - A glass coated steel tank on a concrete base. The tank is in generally good condition except ongoing active leakage around the manway / access point and a joint. Primary Settlement Tank Northeast (4b) - An elevated concrete tank with the outlet channel and walkway cantilevered out from the main structure. The PSTs are all of similar construction and all suffer from similar issues. The structure is in poor condition with numerous, vertical cracks and surface efflorescence. Several cracks are actively leaking. Primary Settlement Tank Southeast (4b) - An elevated concrete tank with the outlet channel and walkway cantilevered out from the main structure. The PSTs are all of similar construction and all suffer from similar issues. The structure is in poor condition with numerous, vertical cracks and surface efflorescence. Several cracks are actively leaking. Primary Settlement Tank Southwest (4b) - An elevated concrete tank with the outlet channel and walkway cantilevered out from the main structure. The PSTs are all of similar construction and all suffer from similar issues. The structure is in poor condition with numerous, vertical cracks and surface efflorescence. Several cracks are actively leaking.
Berwick Hill WWTW	Central	21	3	1	Secondary Trickling Filter (4a) - The filter is a buried brick structure. Delamination has occurred to some of the brick exposed at ground level and there is a lack of toe boards in the perimeter handrailing. There is also ground water infiltration through the walls which may cause further structural decay when the water freezes.
Billingham WWTW	Tees	33,117	36	2	Storm Tank No. 1 (4a) - A below ground concrete structure in average condition. Cracking and ground water ingress to the internal surfaces was observed. Storm Tank No. 3 (4a) - A below ground concrete structure in average condition. There is a crack to the northside of the tank through which ground water is leaking. There is also vegetation growth though the base slab construction joints.
Birtley WWTW	Central	32,858	37	10	Inlet Works Chamber / Reed Bed (4a) - An ageing, in-situ concrete structure with horizontal cracking of the exterior walls with leakage. The handrailing at ground level is slightly rusty but still structurally sound. PST Distribution Chamber (4a) - An elevated, concrete structure which is leaking internally into a room below. The western face is also subject to concrete spalling and exposed reinforcement. Secondary Trickling Filters No. 3 & No. 4 (4a) - Circular, cast in-situ concrete tanks showing full section height vertical cracks at numerous locations around the tank perimeters. Cracking and separation at construction joints.

					Primary Settlement Tank No. 1 (4b) -PST No. 1 has the same construction as 2, 3, and 4 e.g., elevated, above ground cast in-situ concrete. The structure is in poor condition with significant cracking, spalling exposing reinforcement. The tank's internal metalwork e.g., weirs and scum boards, are very corroded. Primary Settlement Tank No. 2 / No. 3 / No. 4 (4b) - All these tanks have the same construction – elevated, above ground cast in-situ reinforced concrete. The issues noted are similar for all three. All three tanks have active leaks, usually from under the cantilevered outlet channel, at numerous locations. There are vertical cracks with associated efflorescence at several locations across the tanks plus spalling which has exposed the reinforcement. The tank's internal metalwork e.g., weirs and scum boards, are very corroded. Secondary Trickling Filter 5 (4b) - A semi-buried structure showing signs of surface cracking at numerous locations with surface staining and wet concrete, indicative of active leaks. Separation of the construction joints and local spalling has exposed the reinforcement at one location. Secondary Trickling Filter 6 (4b) - A semi-buried structure showing signs of surface cracking and efflorescence with some of the cracks actively leaking Secondary Trickling Filter 7 – 8 (4b) - A semi-buried structure showing signs of surface cracking and efflorescence with some of the cracks actively leaking. Secondary Trickling Filter 9 - 10 (4b) - A semi-buried structure showing signs of surface cracking and efflorescence with some of the cracks actively leaking. Filter 10 was assessed to be in the worst condition of all. Sludge Tank (4b) - The tank is an elevated, above ground, reinforced concrete structure. There is an active leak at the base of the structure plus concrete has spalled in several places exposing the underlying reinforcement.
Bishop Middleham WWTW	Tees	1,201	17	4	Inlet & Humus Pumping Station Building (4a) - The pumping station is a brick structure. Horizontal cracks were observed on the internal and external faces. Ground water ingress from a crack in the basement was also observed. Secondary Trickling Filter No. 1 (4a) - The filter is an above ground structure constructed from pre-cast concrete elements. Leaks were observed on the filter overflow unit. The access steps are overgrown with moss presenting a H&S risk. Secondary Trickling Filter No. 2 (4a) - The filter is an above ground structure constructed from pre-cast concrete elements. Leaks were observed on the filter overflow unit. The overflow unit and the access steps appear to have been previously repaired but are again showing signs of cracking. Primary Settlement Tank (4b) - The tank is an above ground concrete structure. Several minor vertical full height wall cracks were observed. One corner has spalling of concrete. There is an active leak at the joint between the wall and outlet channel slab on the southeast corner plus a further leak on the northeast corner.
Bishopton WWTW	Tees	299	8	1	Inlet Structure (4a) - A reinforced concrete structure with severe cracking and spalling, particularly around the inlet pipe where there is leakage. The metallic V-Notch weir is significantly corroded.
Blyth WWTW	Central	37,532	24	2	Storm Tank No. 1 (4a) - The tank is a buried, in-situ concrete structure. Cracks and spalling in the tank base were observed as well as several instances of water ingress in the walls. Storm Tank No. 2 (4a) - The tank is a buried, in-situ concrete structure. Cracks and spalling in the tank base were observed, as well as several instances of water ingress to the north of the tank.
Bolam WWTW	Northumberland	80	6	2	Inlet Works (4a) - Is a brick structure with concrete coping. There is a horizontal crack along the base of the structure which appears to be missing. There is also missing handrailing and access gate. Humus De-Sludge Pumping Station (4b) - The station is a brick building with the external faces showing signs of frost damage. The interior is mouldy indicative of damp, and the wooden access door is rotting in places.
Bran Sands WWTW	Tees	382,321	154	29	Raw Water Booster Pumps & Break Tank (4a) - An above ground unit constructed from what is thought to be GRP. The tank is in poor condition, with a distinctive bulge / deformation of the tank wall on one face. From information on the tank, it is out with its design life (Installed 2005, 10-year life span). SBCO Tank No.1 (4a) - Large diameter, above ground welded steel tank on concrete base, in average to poor condition. There is an active leak at the interface between the tank and the base. SBCO Reception Tank (4a) - Large diameter, above ground welded steel tank on concrete base. Corrosion is visible around the perimeter of the tank at the junction of the tank with the base.

ASP Train A – Cell 1 (4a) - A large, above ground cast in-situ concrete structure. Vertical cracking with a build-up of efflorescence can be seen at several locations. Large, diagonal cracking is seen at every corner which may be indicative of differential settlement. The tank is extensively stained up at the high-level Outlet Channel indicating active leakage. Access steelwork is extensively corroded.

ASP Train A – Cell 2 (4a) - A large, above ground cast in-situ concrete structure. There are large, diagonal cracks are every corner which may be indicative of differential settlement of the structure. There are also instances of cracking with efflorescence indicating active leakage. The access steelwork is poorly supported resulting in excess movement. In addition, the handrailing is deformed in places. The tank appears to be operating above design capacity with minimal freeboard. The additional timber copings are being to rot too.

RSTC Phase 1 Building (4a) - A large, portal steel frame and steel cladding type building which has largely been abandoned, with the active plant localised to the western side of the building which appears to still be active. There appear to be gaps in the cladding. The partial abandonment of the building appears to have encouraged a lot of vermin activity which poses a health and safety risk to Operators.

Sites service north building (4a) - A small portal frame with blockwork and cladding infill. The building is open at one end allowing vermin activity and the interior of the building appears to have an excess of bird excrement, both of which pose a H&S risk to Operators.

Sludge Storage Bund (4a) - The concrete bund for the storage area has a significant crack in the base slab which may allow an escaped liquid to escape containment and contaminate the surrounding ground.

PTA Aeration Tank (TBC) (4b) - An above ground, cast in-situ concrete structure assessed to be in poor condition. There is extensive vertical cracking across the whole structure and a number of these cracks are actively leaking, contaminating the surrounding ground. Efflorescence is also present on other cracks, indicating historic leakage.

SAS Tank No.1 (4b) - An above ground, Glass Coated Steel tank on a concrete base. The tank is in poor condition with degradation of the outer coating and corrosion of the steel panels, especially at the panel joints and pipework penetrations.

SAS Tank No.2 (4b) - An above ground, Glass Coated Steel tank on a concrete base. The tank is in poor condition with degradation of the outer coating and extensive corrosion across the surface, especially at the panel joints. The eastern side of the tank was worst affected.

TAS Storage Tank No.2 (4b) - An above ground, Glass Coated Steel tank on a concrete base, assessed to be in poor condition. The surface coating has degraded extensively across the surface revealing widespread corrosion of the steel panels. TAS Tank No.1 has recently been refurbished or replaced, and Tank No.2 may require similar action.

Sludge Holding Tank No.5 (4b) - A Glass Coated Steel tank on a concrete base structure. The tank itself is in fair to average condition. Large vertical and horizontal cracks can be seen at numerous places around the whole of the base's perimeter. Several of the large cracks have associated efflorescence and can be seen actively leaking into the bunded area.

Sludge Holding Tank No.6 (4b) - A Glass Coated Steel tank on a concrete base structure. The tank itself is in fair to average condition. Large vertical and horizontal cracks can be seen at numerous places around the whole of the base's perimeter. Several of the large cracks have associated efflorescence and can be seen actively leaking into the bunded area.

Sludge Holding Tank No.7 (4b) - A Glass Coated Steel tank on a concrete base structure. The tank itself is in fair to average condition. Large vertical and horizontal cracks can be seen at numerous places around the whole of the base's perimeter. Several of the large cracks have associated efflorescence and can be seen actively leaking into the bunded area. In addition, there is a large horizontal crack to the full perimeter of the base consistent with a construction joint. The crack has significant leakage.

Anaerobic Sludge Digester No.1 (4b) - The digestors are significant cast in-situ concrete structures approximately 20m in diameter and 20m high. They have undergone a separate specialist civil assessment. The tank is in poor condition. Full height vertical cracks around the whole perimeter of the tank, a significant number of which appear to be actively leaking. Significant surface lamination across the whole structure's surface. There is also surface rusting staining indicating corrosion within the tank section of the reinforcing steel.

					Anaerobic Sludge Digester No.2 (4b) - The digestors are significant cast in-situ concrete structures approximately 20m in diameter and 20m high. They have undergone a separate specialist civil assessment. The tank is in poor condition. Full height vertical cracks around the whole perimeter of the tank, a significant number of which appear to be actively leaking. Significant surface lamination across the whole structure's surface. There is also surface rusting staining indicating corrosion within the tank section of the reinforcing steel. Anaerobic Sludge Digester No.3 (4b) - The digestors are significant cast in-situ concrete structures approximately 20m in diameter and 20m high. They have undergone a separate specialist civil assessment. The tank is in poor condition. Full height vertical cracks around the whole perimeter of the tank, a significant number of which appear to be actively leaking. Significant surface lamination across the whole structure's surface. There is also surface rusting staining indicating corrosion within the tank section of the reinforcing steel. Localised instances of concrete spalling have occurred most notably to the base resulting in exposed reinforcement. Raw Sludge Anti-foam dosing kiosk (4b) - A GRP kiosk which has had part of its wall removed to increase access, but which has also increased exposure to the internal equipment to the elements and structurally weakened the overall kiosk. FE Kiosk No.6 (5) - A GRP structure in poor condition. The roof has collapsed resulting in standing water (on the outside) and significant water ingress to the building. There is also vegetation growth. Biofilter PH 2 No.4 (5) - The bio-filter has suffered from extensive fire damage and is no longer fit for operational use. Biofilter PH 2 No.5 (5) - The bio-filter has suffered from extensive fire damage and is no longer fit for operational use. Biofilter PH 2 No.6 (5) - This unit appears in relatively good condition but due to its proximity to the fire damaged filters has been assessed as Grade 5 pending further investigation. Sludge Holding Tank No.1 (5) - A Glass Coated Steel tank on a concrete base structure assessed to be in poor condition. Vertical cracking and efflorescence can be observed to the concrete base. Degradation of the outer coating has allowed extensive corrosion of the steel panels, which is particularly prevalent in the upper third portion where numerous small holes have formed. This represents a H&S risk to Operatives. Sludge Holding Tank No.2 (5) - A Glass Coated Steel tank on a concrete base structure assessed to be in poor condition. Minor vertical cracking can be observed to the concrete base. Degradation of the outer coating has allowed extensive corrosion of the steel panels, which is particularly prevalent in the upper third portion where numerous small holes have formed. This represents a H&S risk to Operatives. Sludge Holding Tank No.3 (5) - A Glass Coated Steel tank on a concrete base structure assessed to be in poor condition. Vertical cracking and efflorescence can be observed to the concrete base. Degradation of the outer coating has allowed extensive corrosion of the steel panels, which is particularly prevalent in the upper third portion where numerous small holes have formed. This represents a H&S risk to Operatives. Sludge Holding Tank No.4 (5) - A Glass Coated Steel tank on a concrete base structure assessed to be in poor condition. Degradation of the outer coating has allowed extensive corrosion of the steel panels, which is particularly prevalent in the upper third portion where numerous small holes have formed. This represents a H&S risk to Operatives. Sludge Tank (5) - A Glass Coated Steel tank sat on a concrete base structure. There are instances of vertical cracking through the base support structure. The eastern pipe penetration is actively leaking sludge. Sludge Mixing Tank (5) - A Glass Coated Steel tank on a concrete base structure assessed to be in poor condition. Degradation of the outer coating has allowed extensive corrosion of the steel panels, which is particularly prevalent in the upper third portion where numerous small holes have formed. The access steelwork to the tank top has extensive corrosion and may not be fit for pedestrian loading.
Browney WWTW	Tees	20,587	39	2	RAS / SAS Pumping Station (4a) - The pumping station is a partially buried, octagonal, reinforced concrete structure deemed to be in poor condition. There are several large, vertical cracks on the external faces plus minor staining and efflorescence. One such crack is actively leaking.

					ASP Feed Chamber (4a) - The chamber is an above ground, reinforced concrete structure assessed to be in poor condition. Localised spalling and surface staining in certain external faces. There is an active leak from a pipe flange.
Butterhaugh WWTW	Northumberland	117	9	2	Control Building (4a) - The structure comprises a brick building with external render on a concrete base with tile roof. Overall, the structure is assessed to be in poor condition. The building as a whole appears to have settled as there is a substantial fall to the base slab and the walls have moved out of plumb. Cracking and spalling of the external render has occurred in several places and the roof is in poor condition with missing ridge tiles, vegetation growth, and missing internal lining. Secondary Trickling Filters No. 1 & No. 2 (4b) - The filter is a semi above ground, octagonal concrete structure assessed to be in poor condition. The external faces suffer from cracking and extensively overgrown with moss and lichen. There are several damp patches which are indicative of leaks. The whole structure has been repaired by installing anchor plates and horizontal tie rods presumably to hold the tanks physically together. According to Site Operatives this system has been in place for 30 years. The central support column is heavily overgrown, and no flow could be seen leaving the filter suggesting the media is clogged or the internal structure / underdrains may have collapsed.
Cambois WWTW	Central	29,411	27	1	Screenings skip building (4a) - The building consists of a steel portal frame with external steel cladding. The roof is extensively corroded with rust holes across the entire surface.
Carlton Redmarshall WWTW	Northumberland	213	12	4	Disused sludge beds (4b) - The old sludge beds have been partially demolished with a section of brickwork retained as a retaining wall. The wall appears to be overturning / failing at points. Site Access Road (4b) - The road suffers from extensive rutting and potholes that make it difficult for larger vehicles to manoeuvre. Secondary Trickling Filter No. 1 and No. 2 (4b) - Brick built trickling filters suffering from cracking, delamination of the brickwork, loose bricks and damaged coping stones. There is no dedicated access to Filters 1 & 2 and as a result the Operator must climb over the dividing wall. Secondary Trickling Filter No. 3 (4b) - Filter 3 has the same issues as Filters 1 & 2 (cracks, loose bricks) but in addition steel bands have been added to hold the filter together. Despite this the filter wall is bulging and leaking from the base and other points.
Carlton in Cleveland WWTW	Tees	244	7	1	Sludge Recirculation Building (4a) - The building is brickwork with a concrete roof. The external brickwork has suffered frost damage, the roof is in poor condition, and the roof drainage pipe is damaged and doesn't connect to the drain. Internally the plasterboard is damp and detaching itself from the brick structure which in one location presents a H&S risk. The sludge pipework within the building is leaking, with visible pooled water. The continuous leakage will ultimately affect the building's structure.
Coalburns WWTW	Central	37	3	1	Primary Settlement Tank No. 1 (4b) - The tanks are constructed from brick with a thin concrete render on the inside, concrete coping and handrailing. The tank is in poor condition with the internal render spalled off at numerous locations across the whole structure. The internal brickwork is in poor condition, with bricks laminating and crumbling. The concrete render remaining also shows signs of horizontal cracking. Transfer and air release pipework is damaged or missing, allowing scum to pass forward rather than be retained.
Cockfield WWTW	Tees	1,637	31	3	Primary Settlement Tank No. 1 (4a) - The PSTs are constructed side by side from reinforced concrete. There is a crack in the division wall between tanks which is actively leaking. There is also an active leak in the tank below the outlet wear. The mortar beds securing the coping stones to the top of the tanks appear to have been washed out in places making the stones loose. Primary Settlement Tank No. 2 (4a) - The PSTs are constructed side by side from reinforced concrete. There is a crack in the division wall between tanks which is actively leaking. The mortar beds securing the coping stones to the top of the tanks appear to have been washed out in places making the stones loose. The operating level of the tank appeared to be very high as well, leaving only 20mm freeboard before discharging to the trickling filters. Retaining Wall (4b) - Brick wall, possibly part of an old tank. The wall appears to have moved and is also showing signs of frost damage.
Consett WWTW	Tees	N/A	48	10	Screw Pumping Station (4a) - The PS consists of a concrete wet well / screw channels with a brick building for the motors / power / control. There are some visible cracks on the above ground screw channels which appear to

					have self-healed. The brick structure has some frost damage and missing bricks. The motor room appears to suffer from damp. Detriter / Grit Area (4b) - An above ground cast in-situ concrete structure which has current active leaks plus signs of past leakage. The channel has been modified at some point and the structure has experienced some delamination of the concrete. Most noticeable is the handrailing steel work which has both corroded and deformed through vehicle impacts. Primary Settlement Tank No. 1 (4b) - The tank is partially buried and formed from reinforced concrete. The tank has multiple vertical cracks some of whom are actively leaking. The coping has pitted and degraded and was observed to have been previously repaired. Primary Settlement Tank No. 2 (4b) - The tank is partially buried and formed from reinforced concrete. The tank has multiple vertical cracks some of whom are actively leaking. The coping has pitted and degraded and was observed to have been previously repaired. The distribution chamber has a loose footpath as well as mortar loss between the coping stones. Secondary Treatment Distribution Siphon Chamber A (4b) - The siphon chambers are above ground concrete structures. Several large vertical and horizontal cracks are present. There is one large, continuous crack around the perimeter of the tank at around 750mm from ground level and which appears to be actively leaking. This may be the result of a defect in the construction process. Secondary Treatment Distribution Siphon Chamber B (4b) - The siphon chambers are above ground concrete structures. Several large vertical and horizontal cracks are present. There is one large, continuous crack around the perimeter of the tank at around 750mm from ground level and which appears to be actively leaking. This may be the result of a defect in the construction process. The perimeter access path is also uneven and represents a trip hazard. Storm Tank No. 1 (4b) - The tank is a buried, cast in-situ concrete structure. Vertical and horizontal cracks were observed at numerous locations, including cracks in the base slab. There were also full height cracks in the dividing wall. The launder channel was leaking, and the weir boards has concrete spalling. Storm Tank No. 2 (4b) - The tank is a buried, cast in-situ concrete structure. Vertical and horizontal cracks were observed at numerous locations. There were full height cracks in the dividing wall and the launder channel was leaking. Weir boards had spalled, and coping stones were loose. Storm Tank No. 3 (4b) - The tank is a buried, cast in-situ concrete structure. Vertical and horizontal cracks were observed at numerous locations. There were full height vertical cracks in the dividing wall and cracking was also observed in the outlet weir. The launder trough was leaking and the concrete slabs that formed the adjacent footpath were loose. Storm Tank No. 4 (4b) - The tank is a buried, cast in-situ concrete structure. Vertical and horizontal cracks were observed at numerous locations. Horizontal cracks were observed in the base and vertical, full height cracks in the dividing wall. The launder channel was observed leaking at multiple locations numerous plus the coping stones are loose due to mortar loss.
Cramlington WWTW	Central	45,918	49	3	Digested Sludge Tank No. 2 (4a) - A GCS tank on a concrete base. The tank roof appears to have deformed / deflected which may indicate partial structural failure. Rust is also observed around the tank base. Access steelwork is also extensively corroded. Sludge Holding Tank (4b) - Is an above ground tank constructed from pre-cast concrete panels. Due to the extensive external staining, it appears the tank has been frequently overtopped. At these locations the panel has undergone erosion / attack and the underlying aggregate and rebar has been exposed. This is particularly prevalent at the top of the tank, at the interface with the roof. Diagonal and horizontal surface cracking is also present. Generator (4b) - The generator is externally housed within a steel container structure. The structure is in poor condition with extensive corrosion across all parts and sections where the panel has rusted right through / disintegrated.

Crookham WWTW	Northumberland	53	7	2	Humus Sludge Pumping Station (4a) - The pumping station consists of a concrete wet well but a wooden aboveground building. The building is weathered, and the roof is missing its waterproof membrane and showing clear signs of rot. The steel mesh covering is unsuitable for pedestrian access (small diameter, widely spaced mesh). MCC Kiosk (4a) - A GRP Kiosk on a concrete base. The kiosk appears to have been damaged on one corner which exposes the internal structure.
Dipton WWTW	Tees	2,829	14	1	Storm Tank No. 2 (4b) - There are two sets of Storm tanks. These are the second set of tanks, located downstream of the inlet channel, and are bespoke concrete tanks rather than repurposed brick, sedimentation tanks. Horizontal and vertical cracking is observed to the internal wall faces, along with efflorescence at the crack sites. Some spalling and damage to the internal, division wall. The wooden boards are rotten and require replacement. The ground to the north of the tank is saturated, which with the settlement of the adjacent footpath, would indicate that there is a significant leak from the tank.
Eastgate WWTW	Tees	56	6	1	Secondary Trickling Filter No. 1 (4a) - A semi-buried brick structure exhibiting delamination and efflorescence on the brickwork, and a leak at one location.
East Tanfield WWTW	Tees	18,390	26	4	Secondary Trickling Filter No. 1 (4b) - Cast in-situ concrete tanks with the vast majority buried underground with only coping stones visible. The true structural condition of the tank is therefore unknown. However, it is noted that the ground around the tank, particularly to the south, was saturated, and a dark liquid was pooling at ground level. This would suggest the tank is structurally compromised and actively leaking. Secondary Trickling Filter No. 2 (4b) - Cast in-situ concrete tanks with the vast majority buried underground with only coping stones visible. The true structural condition of the tank is therefore unknown. The coping stones at the surface are loose and misaligned. As with Tank No. 1 there is a significant amount of standing water around Tank No. 2 and the dark liquid collecting at ground level. This is suggestive of active leakage from the tank. Secondary Trickling Filter No. 3 (4b) - Cast in-situ concrete tanks with the vast majority buried underground with only coping stones visible. The true structural condition of the tank is therefore unknown. As with Tank 1 & 2, the coping stones are loose in places and misaligned along the perimeter. The ground is also noticeably wet but no standing water. Secondary Trickling Filter No. 4 (4b) - Cast in-situ concrete tanks with the vast majority buried underground with only coping stones visible. The true structural condition of the tank is therefore unknown. As with the other tanks, the coping stones are loose and misaligned in places. And again, there appear to be leakage from the tank which is visible from the surface and the surrounding ground is boggy.
East Woodburn WWTW	Northumberland	38	4	1	Inlet Structure and Primary Settlement Tank (4b) - The Inlet structure and the Primary Settlement Tank are constructed as one structure from brick with a concrete internal render / concrete cover slab. The brickwork is damaged resulting in a leak in several places plus the cover slab is damaged.
Edmundbuyer WWTW	Tees	110	10	2	Valve Chamber (4b) - Blockwork valve chamber with buried valve. The above ground portion of the chamber has significant horizontal cracking through the mortar and deterioration of the blockwork itself. Sludge Buffer Tank (4b) - An elevated steel tank sitting on blockwork supports on a concrete base. The tank is in poor condition with extensive corrosion across all surfaces. The support slab also appears to have been undermined by burying animals. Some question as to whether the tank is still in use.
Eggleston WWTW	Tees	265	11	5	Primary Settlement Tanks (4a) - In-situ concrete structure comprising two tanks. There is significant cracking and spalling at a horizontal formwork joint around the tank perimeter. The division wall is leaking and allowing wastewater to flow from one tank to another. Retaining Wall (4a) - A brick retaining wall assessed to be in poor condition. There is a stream behind the wall which results in water leaking through the joints. There are also numerous cracks and frost damaged areas. Siphon Chamber (4a) - A brick structure connected to the downside of the PSTs assessed to be in average to poor condition. There is an active leak from one side which is contaminating the surrounding footpath. Site Building (4a) - The building is a rendered brickwork structure with tile pitched roof. There is some damage to the brick structure. The adjacent sludge beds are actively leaking sludge / supernatant liquid into the inside of the building.

					Sludge Drying Bed (4b) - The beds are buried brick structures with internal division walls creating three separate beds. The beds are in poor condition. The brickwork has been severely degraded plus there's vegetation growth in the mortar beds. There is an active internal leak from one bed to another and a separate external leak from the bed out to the surrounding ground.
Embleton WWTW	Northumberland	729	18	1	Primary Settlement Tank (4a) - Concrete buried structures exhibiting cracking and wear across the tank and an active leak in one location.
Eppleby WWTW	Tees	356	9	1	Site Cabin (4b) - The site cabin is a prefabricated steel (?) cabin which has been elevated and sits on four, single leaf, blockwork columns. Although there is no evidence of movement, the arrangement looks precarious, and the stability of the cabin should be investigated.
Falstone WWTW	Northumberland	178	8	4	Fencing (4b) - Site fencing appears to be a mid-height wooden picket fence. The fence is in poor condition, fallen over in places, and no longer serves its purpose to restrict access to the Works. s Footpath (4b) - The footpath to the PST is a paved concrete path with wooden handrail. The path is steep, overgrown, and the handrail is in poor condition, rotting and degraded. Primary Settlement Tank (4b) - A reinforced concrete structure which is in poor condition. There are cracks and leaks across the whole chamber with heavy moss growth. Secondary Humus Tank (4b) - The tank is a reinforced concrete structure with steel handrailing and walkways. The structure is in poor condition with extensive vertical cracking visible.
Fishburn WWTW	Tees	2,575	24	2	Trickling Filter Distribution Chamber (4a) - The chamber is constructed from pre-cast units and a rectangular concrete surround. Externally there is staining and a crack which is leaking. Internally there is minor vegetation growth. Transfer Pump Chamber (4a) - The chamber is constructed from pre-cast concrete manhole rings with a concrete surround. Externally there is a significant crack which is leaking water into the surrounding ground. Internally there is significant vegetation growth, and it is suspected that the chamber may not be in use.
Frosterly WWTW	Tees	579	14	2	Secondary Trickling Filter (4a) - The filter is a circular brick structure constructed mostly underground. The coping appears to have recently been replaced or repaired. There are vertical and horizontal cracks throughout mostly propagating along mortar lines. The lower brickwork is cracked horizontally which is also leaking. There are areas of efflorescence, and the concrete hardstanding next to the filter is cracked. Sludge Tank 1 (4b) - The tank is a GCS tank within a brick bund. There is a crack in the concrete supporting base along with spalling of the concrete cope and possible vehicle impact damage to the bund itself. There is evidence of leakage from a previous repair on the tank and several rusty patches.
Gainford WWTW	Tees	1,666	14	4	Primary Settlement Tank No. 1 (4b) - The PSTs are brick structures built partially below ground level. The brickwork is heavily frost damaged. There are sections of tank where the coping is close to ground level but there is no edge protection to prevent falls into the tank. Primary Settlement Tank No. 2 (4b) - The PSTs are brick structures built partially below ground level. The brickwork is heavily frost damaged and there are numerous leaks across this PST. There are sections of tank where the coping is close to ground level but there is no edge protection to prevent falls into the tank Secondary Trickling Filter No. 1 (4b) - The filter is a buried brick-built structure in poor condition. The surface of the media is below the top level of the brick walls and the exposed brickwork is in very poor condition with the individual bricks heavily frost damaged, laminated, cracked, and the mortar beds crumbling. The concrete coping stones are loose and have totally detached in places. Secondary Trickling Filter No. 2 (4b) - The filter is a buried brick-built structure in poor condition. The surface of the media is below the top level of the brick walls and the exposed brickwork is in very poor condition with the

					individual bricks heavily frost damaged, laminated, cracked, and the mortar beds crumbling. The concrete coping stones are loose and have totally detached in places.
Great Ayton WWTW	Tees	4,638	13	1	Secondary Trickling Filter [Northern] (4b) - The filter is constructed from semi-buried, pre-cast concrete panels. The exposed, upper parts of the individual panels are showing signs of wear with spalling concrete exposing the rebar, which is corroding. Several of the panels have also moved out of alignment, pulling / dislodging the waterbar and so allowing wastewater to leak out.
Greatham WWTW	Tees	1,017	16	5	Storm Tanks (4a) - The tank is mostly brick built with one in-situ concrete wall. The brickwork displays some frost damage. The surrounding concrete walkway is cracked and displaced indicating there might be some underlying movement or instability. Primary Settlement Tank No.2 (4a) - A brickwork structure with concrete coping which has multiple active leaks across the structure. Sludge Holding Tank (4a) - An above ground concrete tank which appears to have been regularly overtopped. The resultant discharge appears to have helped corroded the outer face of the tank exposing aggregate and also destroying the top surface on which the cover sits. Primary Settlement Tank No. 1 (4b) - A brickwork structure where a significant section of one corner appears to have moved or settled resulting in a major crack. The corner section appears to have separated from the remainder of the structure. Secondary Humus Tank No. 1 (4b) - A partially buried brickwork structure with several significant vertical and horizontal cracks which allow process water to escape into the surrounding ground.
Gunnerton WWTW	Northumberland	172	6	1	Secondary Humus Tank (4a) - A brick tank with a concrete coping, in average condition generally but with one section in a much poorer state which shows signs of efflorescence and vegetable growth. There may also be groundwater intrusion.
Haydon Bridge WWTW	Northumberland	1,600	16	2	Storm Tanks No. 1& No. 2 (4a) - The tanks are brick with an internal concrete lining. Externally the brickwork is displaying lamination, spalling, mortar loss and just general degradation at various points. Internally the concrete lining is deteriorating with general lamination across the structures and a large crack in the base of one tank. Sludge Area / Sludge Chamber (4a) - A cast in-situ concrete chamber and working area. The edges of the chamber / working surface have degraded and there is exposed aggregate. The whole area around the tank and the lowered working area have been inundated with sludge due to the overtopping of the liquor return pumping station.
Heddon Hall WWTW		20	4	1	Inlet Chamber & Primary Settlement Tank (4b) - The Inlet and PST is built monolithically as one structure from brick with a concrete cover slab. The overall structure is in poor condition with cracking to the haunching, damage to mortar lines, and loose brickwork. There is also an active leak contaminating the surrounding ground with wastewater.
Hexham WWTW	Northumberland	14,500	11	2	Secondary Trickling Filters (Units 1/2/3/4) (4b) - Above ground engineering brick filters. There are numerous significant horizontal and vertical cracks throughout all four filters which are currently being held together with bearing plates and tension cables. This structural system was installed between 10 and 15 years ago. When this system reaches the end of its working life it is likely that the filters will need to be replaced. Consequently, the filters are currently graded 4b, but failure of the tensioning system will change the classification to 5. Trickling Filter Distribution Chamber (4b) - The chamber is a double skinned engineering brick structure with an internal sealing / membrane and concrete coping stones. There are large vertical and horizontal crack son multiple sides of the structure causing efflorescence and one instance the wall to move away from the rest of the structure. The coping stones are also loose.
Holmside WWTW	Tees	N/A	4	1	Rotating Biological Contactor (4b) - Only the above ground portion of the RBC could be assessed, which is a GRP cover in poor condition. The cover's condition has deteriorated due to external exposure and UV degradation. The cover also has several cracks and overall is sagging badly.

Hustledown WWTW	Tees	14,756	12	1	The Atkins survey report does not grade any of the assets as 4a/4b/5, however, NWL's ongoing, "live" asset grading summary does note the sludge area as condition 4a. Sludge Storage Area (4a) - Above ground concrete storage tanks. Some horizontal cracks near the base with some evidence that these cracks have leaked. Requires monitoring.
Hutton Rudby WWTW	Tees	1,841	20	3	Primary Settlement Tank (4a) - A monolithic structure comprising two separate tanks and assessed as being in poor condition. There is extensive cracking and delamination to all exposed sides of the tank. While there is no exposed rebar yet, this will reduce the life span of the structure. The timber scum boards are rotten. Secondary Trickling Filter Distribution Chamber (4a) - The chamber is a semi-buried cast in-situ concrete structure assessed to be in poor condition. There is a horizontal crack that runs around the perimeter of the walls which appears to be associated with a construction joint and is actively leaking. The crack also has vegetation growing from it. Sludge Return Pumping Station and Chamber (5) - A GRP kiosk plus open topped concrete wet well. Although the kiosk is showing some signs of age-related wear (fading and UV related degradation) the main concern is the operation of the asset. The sludge wet well is undersized and the coping level too low in relation to upstream processes so that when the PST de-sludges the wet well overtops, flooding the area. This occurs frequently creating a H&S risk.
Ingoe WWTW	Northumberland	60	5	2	Secondary Trickling Filter (4a) - An above ground rectangular brick structure which is assessed to be in poor condition. There are major cracks of greater than 5mm width with associated efflorescence across all sides of the filter. The cracking is through the brickwork itself rather than along the mortar planes, which would suggest this is indicative of differential settlement. There is a minor leak to one side. Inlet & Primary Settlement Tanks (4b) - The structure is constructed from brick walls with pre-cast concrete slab covers. The structure is in poor condition. There is delamination and leaks to the external brickwork and several pre-cast slabs appear to be missing leaving the tank partly open.
Kelloe WWTW	Tees	2,051	26	1	FE Recirculation Pumping Station (4a) - The pumping station is a brick building with a flat concrete roof and brick wet wells, all assessed to be in poor condition. The brickwork chamber has a build-up of efflorescence along the mortar lines as well as an active leak. The wet well brickwork also has signs of lamination.
Langley WWTW	Northumberland	26	3	1	Secondary Trickling Filter (4a) - The filter is an above ground brick structure in poor condition. The external face is subject to extensive spalling and lamination and there are several active leaks. The upstream PST leaks into the filter media.
Leamside WWTW	Central	N/A	22	4	Secondary Trickling Filter No. 1 (4a) - A structure constructed from brickwork but with pre-cast concrete panels bolted together and added retrospectively to the sides of the filter that sit above ground. Where visible the exposed brickwork has signs of lamination / frost damage. The outlet channel is also filled with filter media suggesting the internal support structures have collapsed. Secondary Trickling Filter No. 2 (4a) - A structure constructed from brickwork but with pre-cast concrete panels bolted together and added retrospectively to the sides of the filter that sit above ground. Where visible the exposed brickwork has signs of lamination / frost damage. The outlet channel is also filled with filter media suggesting the internal support structures have collapsed. Secondary Humus Return Pumping Station (4b) - The pumping station is a brick-built building sitting on a concrete base slab, with a flat roof, and deemed to be in poor condition. There is extensive horizontal and vertical cracking to all sides of the building through the brickwork as well as the mortar. Skip Building (4b) - The building is a small, domestic garage sized, steel building sitting on a concrete base. The building is in poor condition with extensive rusting across all surfaces
Lockhaugh WWTW	Central	12,689	33	4	Storm Tank No. 1 (4b) - Buried, cast in-situ reinforced concrete structure deemed to be in poor condition. There is widespread cracking. There is water ingress at a horizontal construction joint.

					Storm Tank No. 2 (4b) - Buried, cast in-situ reinforced concrete structure deemed to be in poor condition. There is widespread cracking. There is water ingress at a horizontal construction joint. Storm Tank No. 3 (4b) - Buried, cast in-situ reinforced concrete structure deemed to be in poor condition. There is widespread cracking. There is water ingress at a horizontal construction joint. Storm Tank No. 4 (4b) - Buried, cast in-situ reinforced concrete structure deemed to be in poor condition. There is widespread cracking. There is water ingress at a horizontal construction joint.
Longbyre WWTW	Northumberland	80	4	1	Secondary Trickling Filter (4b) - The filter is an above ground, octagonal, reinforced concrete structure which is assessed to be in poor condition. There are horizontal and vertical cracks greater than 0.5mm and are actively leaking in several places. Efflorescence, spalling, and lamination of the concrete is visible in several locations. Vertical joints and sealant have been recently repaired.
Low Wadsworth WWTW	Tees	16,558	35	4	Storm Tank No. 1 (4b) - The tank is a below ground cast in-situ concrete structure. Extensive horizontal and vertical cracking on the internal faces. Horizontal cracking along the dividing wall has active leaks along its length. Concrete coping stones are spalling. Storm Tank No. 2 (4b) - The tank is a below ground cast in-situ concrete structure. Extensive horizontal and vertical cracking on the internal faces. Horizontal cracking along the dividing wall has active leaks along its length. Concrete coping stones are spalling. Storm Tank No. 4 (4b) - The tank is redundant and has been allowed to become heavily overgrown particularly at base construction joints. Secondary Trickling Filters 1-4 Siphon Chamber (4b) - An octangular, buried, concrete structure. Significant cracking, spalling, and joint separation is observed at the corners resulting in extensive leaks.
Low Worsall WWTW	Tees	N/A	14	5	PST Distribution Chamber (4a) - A brick chamber with a concrete coping. There is spalling and delamination of the brickwork. In one section there was a crack that was leaking. Primary Settlement Tank No. 1 (4b) -Brickwork structure with concrete base. The overall structure is classed as poor with multiple leaks and the outlet side wall has moved out of vertical alignment and is in danger of collapse. Secondary Trickling Filter No. 1 (4b) - A circular brick structure which is assessed as being in poor condition. There is missing and cracked mortar plus signs of leakage on its western side. Secondary Trickling Filter No. 2 (4b) -A circular brick structure which is assessed to be in poor condition. The exposed brickwork side has multiple leaks. Sludge Tank (4b) - A semi buried brick structure with concrete coping assessed to be in poor condition. There are multiple leaks, and the covers are not adequately secured.
Lynemouth WWTW	Northumberland	6,494	23	2	Pumping Station Building (4a) - The building is a reinforced concrete framed structure with brick externals and concrete roof panels. The roof appears to be leaking into the administration room below through a gap / failed joint in the roof panels. Primary Settlement Tank No. 1 (4b) - A partially buried concrete structure. Spalling of the concrete has exposed the rebar in some areas resulting in corrosion. Pitting and cracking was observed across the structure.
Marske WWTW	Tees	88,880	34	1	SBR Tank No. 4 (4a) - In-situ concrete tank with vertical cracks and an active leak on the south wall.
Middleton in Teesside WWTW	Tees	1,109	12	1	Sludge Holding Tanks (4a) - The sludge holding tanks are semi-buried brick structures with concrete coping stones. There is extensive damage to both brickwork (lamination) and mortar along the whole tank perimeter. It is evident that both tanks are leaking from their north sides, which have been repaired previously.
Mitford WWTW	Northumberland	213	6	1	Secondary Trickling Filter (4b) - The filter is a semi-buried brick structure assessed to be in poor condition. There are a significant number of leaks caused by extensive mortar decay. The concrete coping is also damaged and chipped.
Nenthead WWTW	Tees	315	10	1	Preliminary Buffer Tanks (4b) - The tanks are above ground painted steel tanks sat on concrete pad foundations. The tanks have widespread corrosion across the external surfaces and extending to the base flanges. No leaks visible. Tanks may not be in use.

Newby WWTW	Tees	N/A	6	1	Sludge Storage Tank (4a) - The tank is a buried, reinforced concrete tank assessed to be in average to poor condition with a vertical crack in one corner which allows ground water infiltration. The pre-cast concrete copings are loose.
Park Village WWTW	Northumberland	48	6	2	Preliminary Inlet Chamber (4a) - An above ground brick masonry structure with mass concrete coping / haunching. The external faces exhibit signs of leakage and efflorescence. There is leakage where the pipe penetrates the chamber. The concrete coping shows signs of cracking in one corner. Secondary Trickling Filter (4a) - The filter is an above ground brick structure on a concrete base with circular external outlet channel. The filter is assessed to be in poor condition. The brickwork shows signs of efflorescence and staining plus there's missing brickwork. The outlet channel is cracked and spalled in several locations. In addition, gravel / stones from the surrounding land have been washed into the channel.
Pittington WWTW	Tees	1,542	19	8	Storm Tank No. 1 (4b) - Rectangular brickwork tank build adjacent to Tank 2. A crack was observed in the common division wall between Tanks 1 & 2 and the outlet launder channel. The inlet weir appeared to be leaking. Open mesh flooring has not been properly secured down. Storm Tank No. 2 (4b) - Rectangular brickwork tank built adjacent to Tank 1. A crack was observed in the common division wall between Tanks 1 & 2 and the outlet launder channel. A significant leak in Tank 2 was observed which is contaminating the surrounding ground. Open mesh flooring has not been properly secured down. Primary Settlement Tank No. 1 (4b) - The tank is a below ground structure constructed from both brickwork and concrete. Cracks in the walls and coping were observed. All tanks were observed leaking into their respective valve chambers suggesting the external wall is damaged below the operational waterline. Access mesh flooring was not properly secured and handrailing was loose in places. Primary Settlement Tank No. 2 (4b) - The tank is a below ground structure constructed from both brickwork and concrete. Cracks in the walls and coping were observed. All tanks were observed leaking into their respective valve chambers suggesting the external wall is damaged below the operational waterline. Access mesh flooring was not properly secured and handrailing was loose in places. Primary Settlement Tank No. 3 (4b) - The tank is a below ground structure constructed from both brickwork and concrete. Cracks in the walls and coping were observed. All tanks were observed leaking into their respective valve chambers suggesting the external wall is damaged below the operational waterline. Access mesh flooring was not properly secured and handrailing was loose in places. Primary Settlement Tank No. 4 (4b) - The tank is a below ground structure constructed from both brickwork and concrete. Cracks in the walls and coping were observed. All tanks were observed leaking into their respective valve chambers suggesting the external wall is damaged below the operational waterline. Access mesh flooring was not properly secured and handrailing was loose in places. Abandoned Sludge Tank No. 1 (5) - An above ground Glass Coated Steel tank on a concrete base slab. There are large holes in the tank side and extensive rusting. Abandoned Sludge Tank No. 2 (5) - An above ground Glass Coated Steel tank on a concrete base slab. There are large holes in the tank side and extensive rusting.
Pity Me WWTW	Tees	1,284	9	3	Primary Settlement Tank (4a) - A brickwork structure with pre-cast concrete coping. The structure is in overall poor condition showing vertical and horizontal cracking on the external face with signs of leakage. The coping is loose with degrade mortar. Surcharged water escaped from the noted manhole has flooded the area around the tanks. Secondary Trickling Filter 1&2 (4b) - Brick structures on concrete bases and concrete coping assessed as being in average to poor condition. The brickwork is cracking along mortar lines and there are numerous leaks, particularly at the interface between brick and concrete base. Across the filters outlets appear to be blocked with little to no flow observed suggesting the floor under drain tiles have collapsed.

					Manhole Chamber d/s storm tanks (5) - Pre-cast concrete chamber with concrete coping / cover. The concrete haunching / cope at the surface appears to be cracked. The manhole appears to have been surcharged with the chamber frame lifted and actively leaking process water across the site.
Rothbury WWTW	Northumberland	2,080	28	3	Primary Settlement Tank No. 4 (4a) - A partially buried concrete tank. Extensive moss growth on the internal surfaces. Temporary covers made from timber and wire mesh have been installed across the tanks but are totally unsuitable for pedestrian loading and are in poor condition. Storm Tank No. 1 (4b) - A partially buried in-situ concrete structure. There are multiple instances of exposed aggregate as well spalling and delamination of the coping stones. The launder channel appears to be leaking and there is a thick layer of sludge across the bottom of the tank. Storm Tank No. 2 (4b) - A partially buried in-situ concrete structure. There are multiple instances of exposed aggregate as well spalling and delamination of the coping stones. The launder channel appears to be leaking and there is a thick layer of sludge across the bottom of the tank.
Sadberge WWTW	Tees	569	6	4	Macerator (4a) - An elevated cast in-situ concrete structure with an MCC room under the flow channel. The structure appears to be in generally good condition aside from small section of exposed rebar and a small external leak. The handrailing is generally in good condition but needs repainting plus some missing edge protection and access gate. Primary Settlement Tanks (4a) - Above ground concrete structures with an external weir. The structure has cracking throughout but only one of these has turned into an active leak. The launder channel has exposed aggregate due to constant erosion from the process water. The access walkway to the tanks is too narrow and doesn’t meet current company requirements. It is also noted that one of the launder channels is dry suggesting a hydraulic or level issue with the channel. Secondary Trickling Filter No. 1 (4b) - An above ground structure constructed from a post tensioned pre-cast concrete wall system sitting on a concrete base. The tank exhibits leakage at the junction between the wall panel and the base slab. For this tank, the leakage is approximately one quarter of its perimeter. Secondary Trickling Filter No. 2 (4b) - An above ground structure constructed from a post tensioned pre-cast concrete wall system sitting on a concrete base. The tank exhibits leakage at the junction between the wall panel and the base slab. A brickwork chamber on this filter is pulling away from the main structure and in danger of falling over.
Scots Gap WWTW	Northumberland	221	9	2	Secondary Trickling Filter No. 1& No. 2 (4b) - Above ground brick structures which have a number of small leaks around their perimeters. The footpaths around the filters are overgrown and slippy. Humus Sludge Return Pump House (4b) - The pump house is in poor condition with large cracks in the external wall and the concrete render has broken off exposing the underlying brickwork. There is also concrete spalling from the underneath of the roof. The floor of the pump house is covered with dried rags and wastewater due to pump blockages causing the level of the wet well to rise and then seep in through poorly sealed pipe penetrations.
Seaton Carew WWTW	Tees	119,725	26	1	Lamella Plant Internal Building (4a) - The lamella plant consists of an above ground reinforced concrete structure with step access to the roof, an internal area at ground level, and a below ground basement. In the internal area there are multiple, overhead leaking pipes which have corroded the concrete base beneath and exposed the aggregate. There are small, localised cracks which are also leaking and show signs of staining, efflorescence and rusting. Several cracks are actively leaking.
Sedgeletch WWTW	Tees	51,589	24	8	Inlet Works including Detritor & Storm Weir (4a) - This is an elevated, cast in-situ concrete structure. Damage and spalling can be seen at the DWF overflow weir. Degradation of inlet joint sealant is observed – these joints also appear to have been previously over-banded or repaired. Around the structure multiple cracks, active leaking with staining indicative of corrosion. Large vertical cracks at numerous locations for the full depth of the structure again leaking into the environment. Localised instances of concrete spalling with exposed reinforcement. Primary Settlement Tank No. 1 (4a) - Semi-buried, circular, cast in-situ concrete tanks with a cantilevered section for the outlet launder and perimeter walkway. The steel handrailing in general requires painting. Cracks to the

					external face of the tank are observed leaking in places and there are localised examples of spalling under the walkway where rebar steel has been exposed. The installation of the handrail has damaged the concrete walkway. Primary Settlement Tank No. 2 (4a) - Semi-buried, circular, cast in-situ concrete tanks with a cantilevered section for the outlet launder and perimeter walkway. The steel handrailing in general requires painting. Cracks to the external face of the tank are observed leaking in places and there are localised examples of spalling under the walkway but no exposed rebar. The installation of the handrail has damaged the concrete walkway. Primary Settlement Tank No. 3 (4a) - Semi-buried, circular, cast in-situ concrete tanks with a cantilevered section for the outlet launder and perimeter walkway. Sealant is in poor conditions at joints and there is surface staining and leakage. Primary Settlement Tank No. 4 (4a) - Semi-buried, circular, cast in-situ concrete tanks with a cantilevered section for the outlet launder and perimeter walkway. The concrete coping has been previously repaired, but this repair is now failing, and concrete is spalling off. A leak can be observed on the external face at the interface with the distribution chamber walkway. The internal steel scum ring is rusted and deteriorated. ASP Tanks (4a) - Buried, cast in-situ concrete tanks assessed to be in poor condition. Significant spalling has occurred to one corner of the cantilevered walkway resulting in exposed rebar. Sealant at the middle movement joint is in a very poor condition and all other joint locations across the structure are in poor condition either degraded or missing altogether. The movement joints appear to have opened up significantly. Storm Tanks (4a) - Buried cast in-situ reinforced concrete structures. The internal faces of the tanks appear to have eroded exposing the aggregate. There is also significant cracking to the division wall between the two tanks. The precast slab perimeter path is also uneven. Nitrifying Trickling Filters (5) - Above ground tanks constructed from pre-cast concrete panels set into a concrete base. The panels are cracked and weeping. The support system to the internal media appears to have collapsed. Concrete has spalled from a panel around a pipe penetration but does not appear to be leaking. Access steps are missing a handrail.
Sherburn House WWTW	Tees	39	10	1	Transfer Siphon Chamber (4a) - The Siphon Chamber is a series of rectangular brick chambers which sit downstream of the PSTs. The structure has been treated with a rubberized, protective coating in an attempt to extend the structure’s life. There is evidence of frost damage to the bricks and a leak at the joint between the brick wall and concrete base slab.
Skinningrove WWTW	Tees	8,176	20	1	Inlet Works Distribution Chamber (4a) - The chamber is an above ground concrete structure with horizontal cracking at several levels on several wall faces. These horizontal cracks may be related to construction joints.
Stamfordham WWTW	Central	471	11	1	Secondary Trickling Filters No. 1 & No. 2 (4b) - The two filters are built in brick as an above ground monolithic structure assessed to be in poor condition. The structure has severe cracking in multiple locations through the external brick walls. Differential settlement may have occurred on one side since the walls appear to be moving out of plumb and pulling away from the rest of the filter. The filter is also leaking from several cracks.
Stokesley WWTW	Tees	8,014	25	1	Inlet Works (4a) - The inlet works is an elevated reinforced concrete structure assessed to be in average to poor condition. Large areas of concrete spalling / delamination with exposed, corroding rebar are observed across the full extent of the structure, especially to the support walls. There appears to be an active leak on the inlet channel with wastewater running down the support walls.
Stonehaugh WWTW	Northumberland	73	10	1	Primary Settlement Tanks (4a) - The tanks are above ground structures comprising an inner concrete section and an external brick skin. Cracking and spalling of the inner concrete structure was observed in one of the tanks currently drained down. There is also an active leak through the tank that’s currently in use. The handrailing and other steel components (e.g. toe boards) are heavily corroded.
Trimdon WWTW	Tees	4,455	19	2	Secondary Trickling Filter No. 3 (4a) - Tank built from multiple pre-cast sections with a significant mass concrete haunch (for stability?) running around the perimeter at the base. The sealant between panels appears to have become brittle, cracked and debonded from the panels. Some leakage.

					Trickling Filter Distribution Chamber (4b) - An above ground concrete structure. There are multiple active leaks localised toward the base / ground level and centred around cracks or areas where the concrete has spalled. Minor vegetation growth within the chamber.
Ushaw Moor WWTW	Tees	33	9	1	Secondary Humus Return Pumping Station (4b) - The pump appears to be housed in a buried concrete chamber topped by a small wooden hut with a pitched roof. The above ground wooden hut is rotten and missing its waterproof roof membrane.
Wark WWTW	Northumberland	445	5	2	Sludge Holding Tank (4a) - Two brick tanks with concrete coping, one of which aren't in use. Minor cracking to mortar joints with brickwork lamination and active leakage on one side contaminating the surrounding ground. Coping stones are very overgrown with moss and displaced in areas. Inlet Works & Primary Settlement Tank (4b) - An elevated, above ground brick structure with concrete coping, assessed to be in poor overall condition. The brickwork shows extensive cracking and leaking on all sides. The north side in particular has horizontal cracking through the mortar line and joint separation as well as leakage. The structure has previously been repaired but is showing signs of further cracking. The access grating was loose and requires to be properly secured.
Washington WWTW	Central	69,777	17	3	Primary Settlement Tanks No. 1 & No. 2 [DISUSED] (4b) - From discussions with site staff, Tanks 1 and 2 are no longer in use due to operational issues. The tanks are large, rectangular, cast in-situ concrete structures. One side appears to have settled more than the other post construction resulting in a step forming within the tank, joint separation, and a level change in the cope. There is vertical cracking at this location. The joints generally are in poor condition with the sealant separating / pulling away. There are also areas of concrete cracking and spalling. Primary Settlement Tanks No. 3 & No. 4 (4b) - Rectangular cast in-situ concrete structures. As with Tanks 1&2, one side of tanks 3&4 appears to have undergone more settlement than the other resulting in a step forming in the cope. There is some surface cracking visible in the coping, but this may just be superficial. Slight joint separation at some locations. Storm Tanks No. 1 & No. 2 (4b) - The concrete, cast in-situ storms tanks appear to form part of the same overall structure as the PSTs and as such have experienced the same differential settlement issues resulting in a defined step visible in the coping and base. Localised spalling has occurred to the dividing wall. Joint sealant can be seen in the base slab bays. Exposed, displaced water bar is visible at several joint locations. In one area of Tank 2, there has been severe spalling/lamination along the coping for most of the tank's length. The tank's internal faces have also experienced minor lamination. A section of tank does not have adequate edge protection.
Wear Valley Junction WWTW	Tees	36	4	1	Secondary Trickling Filter (4a) - The filter is an above ground, brick structure on a concrete base. The filter was observed to be leaking in several areas, with associated efflorescence on the external brick face. The handrail around the top of the filter has been destroyed by a fallen tree.
Western Area WWTW	Tees	1,065	17	1	Secondary Trickling Filter No. 1 (4a) - A buried, brick structure with a concrete coping. There is a vertical crack through the brickwork structure itself and horizontal cracking under the coping, separating the coping from the rest of the filter. There is evidence of some leaking through the wall.
Whalton WWTW	Northumberland	N/A	15	1	Distribution Chamber (4a) - An above-ground reinforced concrete structure assessed at being in poor condition. The structure appears to be leaking at one of the outlet pipes with efflorescence on the concrete surface.
Whittingham WWTW	Northumberland	231	8	1	Secondary Trickling Filter (4a) - Partially buried in-situ concrete tank. Large, vertical cracks to external faces which appear to be actively leaking. Minor hairline cracking to the tank coping. Possible blockage to outlet chamber.
Whittonstall WWTW	Tees	74	5	1	Buffer Tank (4a) - The above ground tank is steel on a concrete base slab. The tank is assessed to be in average to poor condition with corrosion across its surfaces. There is also corrosion to the tank's main structural members.
Willington WWTW	Tees	9,593	25	6	Primary Settlement Tank No. 1 (4a) - An above ground reinforced concrete structure assessed to be in poor condition. The tank has several vertical and horizontal cracks in both the upper and lower areas. Concrete has spalled off in several areas, exposing the underlying reinforcement which is heavily corroded. The tank itself is

					surrounded by standing water but it couldn't be confirmed whether this was trapped surface water or wastewater that had leaked from the tank. Primary Settlement Tank No. 2 (4a) - An above ground reinforced concrete tank assessed to be in poor condition. There are several areas of efflorescence on the structure's base. As with Tank No. 1 there are several vertical and horizontal cracks in the structure with concrete spalled off and exposed corroded reinforcement. Distribution Chamber for Trickling Filters No. 1 to No. 4 (4a) - An above ground reinforced concrete structure with several vertical, full height cracks on the external walls. One crack is actively leaking. Secondary Trickling Filter No. 7 & No. 8 (4a) - The two filters are constructed as one conjoined concrete structure with pre-cast coping stones. The filters are assessed as being in poor conditions. There are numerous vertical and horizontal cracks plus areas where the concrete has spalled off and exposed the reinforcement which is corroding. There is also separation and degradation of the construction joints. Sludge Holding Tanks No. 1 & No. 2 (4a) - An above ground reinforced concrete tank with horizontal cracking at the lower levels of the external faces, exposed aggregate and corroding rebar. Inlet Works (4b) - An elevated, above-ground structure assessed to be in poor condition overall. There are several areas across the whole structure where the concrete has crazed and spalled exposing the reinforcement. Large horizontal cracks are present with efflorescence. The structure is leaking in several places, particularly at the wall / base joint on the inlet channel. Several construction joints have separated, and sealant has degraded.
Windlestone WWTW	Tees	9,746	38	1	Storm Tank No. 3 (4a) - Partially buried reinforced concrete tank that has previously undergone repairs to a crack in its base. Ground water from outside was observed to be leaking into the tank at 150mm above base level.
Winston WWTW	Tees	254	10	1	Access Steps (4a) - Wooden steps from Trickling Filter to lower Humus Tank area. Handrailing provided on one side only plus risers are degrading leading to collapse of steps.

13. ANNEX 5 – THE CONSEQUENCE OF FAILURE FOR CIVIL ASSETS

In section 6.1.3, we summarised our approach to assessing the consequences of failure for civil assets. In Annex 5, we explain this in more detail.

13.1. ASSESSMENT OF CONSEQUENCE

We have applied an intensive process of engaging experts to gather and validate the assessment of consequence of asset failure. This section describes the four stages of this process and the individual steps in those stages; it also includes an illustrative case-study to demonstrate the application of the process. This section concludes with a summary of the results of the consequence assessment process.

This assessment is not intended to provide a full cost-benefit assessment, as such analysis would require a robust estimate of likelihood. We have used a subjective, expert-judgment based view of likelihood in the process of prioritisation. Our final quantification of the consequence does not use a robust estimate of likelihood, as there are not sufficient examples of failures historically to be able to estimate likelihood robustly[58].

13.1.1 Stage 1 – Categorisation and prioritisation

We have assessed 81 WTW and 189 STW unique assets as being in condition grade 4 as part of the survey programme. To avoid the duplication of effort, we categorised these assets to determine which consequence assessments are likely to be similar, for example, because they are the same asset type (such as clarifiers at Honey Hill WTW and Mosswood WTW, which are broadly similar).

For each of these categories we selected a representative example asset to be subject to the full process of assessment. To make sure the results of this assessment can then be individualised to each of the other assets within the category, we:

- Identified specific considerations which would influence the assessment for other assets[59] (this step is discussed further in stage 2).
- Identified specific values which are material to the consequence assessment[60] for each asset within the category (this step is discussed further in stage 3).

[58] This lack of historic evidence is, we believe, due to two factors. Firstly, the age profile of the asset cohorts we are considering here are now beginning to reach the end of their life and so we would not expect much evidence of previous failures. Secondly, where these assets do reach a condition of imminent failure (condition grade 5) they are by and large identified by operational staff and subject to emergency remediation, which places pressure on other maintenance budgets. This case advocates for proactive investment to obviate the need for emergency repairs.
[59] For example, the proximity of the asset to a waterbody, the status of the waterbody and the relative size of the asset and the waterbody might influence the likelihood and severity of a potential pollution incident resulting from asset failure.
[60] For example, the flow through an asset is material to understand the scale and hence cost of temporary plant that might be required to bypass a failed asset as part of a short-term mitigation of failure.

From the categorised list of assets, we prioritised these for assessment through a subjective workshop discussion with multiple experts and the accountable owner of this area of the business plan. This workshop style discussion was informed by an understanding of the scale of problem each asset represents based on the following data:

- The number of assets which are within the group that this asset represents.
- The total scale of costs for solutions to address the assets within the group. This includes a “group level” Monte Carlo assessment of potential cost as well as the sum of the three-point estimates.
- A subjective judgement of potential likelihood and consequence of failure for the assets within the group based on two axes five-point scale (see the example in Figure 76 below).

FIGURE 76: LIKELIHOOD AGAINST SEVERITY OF CONSEQUENCE

Likelihood						
5	Likely to be multiple asset failures in AMP8	5	10	15	20	25
4	Likely to be one asset failure in AMP8	4	8	12	16	20
3	50% chance of asset failure in AMP8	3	6	9	12	15
2	20% chance of asset failure in AMP8	2	4	6	8	10
1	<5% chance of asset failure in AMP8	1	2	3	4	5
	Severity of consequence	Not material	Minor	Moderate	Major	Catastrophic
		1	2	3	4	5

The results of this prioritisation are shown in Figure 77 for the water service and Figure 78 for the wastewater service overleaf.

FIGURE 77: RESULTS OF PRIORITISATION FOR CIVIL ASSETS - WATER

Priority	Asset Group	Assets within the group		Potential capital cost to resolve (22/23 prices)			
		Nr.	Example of assets	50th percentile	Best case	Most likely	Worst case
VH	Raw water reservoir	2	Langford WTW East raw water reservoir	£10.14m	£3.79m	£9.46m	£18.83m
H	Vertical flow treatment tank	22	Honey Hill WTW clarifiers	£5.65m	£1.40m	£6.06m	£10.00m
H	Building – process	28	Hanningfield WTW ozone dosing room	£2.45m	£1.36m	£2.21m	£2.96m
H	Slow sand filters	3	Ormesby WTW slow sand filter 5	£1.78m	£0.62m	£1.32m	£1.80m
H	Treated water storage	3	Walpole WTW treated water storage tank	£1.61m	£0.01m	£1.38m	£1.64m
M	GAC / iron filter	6	Hanningfield WTW GAC contactor leak	£0.87m	£0.55m	£0.83m	£0.85m
M	General access	7	North Dalton WTW well 3 gantry	£0.52m	£0.19m	£0.48m	£3.26m
M	Sludge tanks	4	Honey Hill sludge mixing/balancing tank	£0.33m	£0.05m	£0.31m	£0.52m
M	Filter backwash	2	Walpole WTW backwash tank	£0.59m	£0.01m	£0.54m	£1.08m
M	Building – stores	4	Barsham WTW fuel store building	£0.24m	£0.18m	£0.22m	£0.40m

FIGURE 78: RESULTS OF PRIORITISATION FOR CIVIL ASSETS - WASTEWATER

Priority	Asset Group	Assets within the group		Potential capital cost to resolve (22/23 prices)			
		Nr.	Example of assets	50th percentile	Best case	Most likely	Worst case
VH	Storm tank	26	Consett STW storm tank 1	£4.91m	£2.10m	£4.18m	£6.27m
H	Inlet works	15	Consett STW detritor	£2.73m	£0.69m	£1.90m	£4.29m
H	PST[61]	35	Birtley STW PSTs 1-4	£17.53m	£8.09m	£13.47m	£22.08m
H	ASP[62]	5	Sedgeletch STW ASP tanks	£11.69m	£10.40m	£10.42m	£17.07m
H	Distribution chamber	18	Birtley PST distribution chamber	£0.98m	£0.23m	£0.48m	£1.24m
H	Sludge tank	23	Birtley STW sludge tank	£2.74m	£1.01m	£2.55m	£6.42m
H	Trickling filter	32	Birtley STW trickling filters 5-10	£57.57m	£11.40m	£45.85m	£71.50m
M	Sludge digester	3	Bran Sands STW sludge digester 2	£0.38m	nil	£0.36m	£18.27m
M	Pumping station	8	Consett STW screw pump station	£0.19m	£0.11m	£0.19m	£0.26m
M	Treatment – other	1	Holmside STW RBC[63]	£1.55m	£0.01m	£1.53m	£1.53m
M	General access	8	Eggleston STW retaining wall	£0.38m	£0.10m	£0.38m	£0.54m
M	Building	10	Seaton Carew STW lamella plant building	£0.36m	£0.13m	£0.34m	£0.64m
M	Humus tank	2	Gunnerton STW humus tank	£0.24m	£0.06m	£0.23m	£0.33m
L	Chemical dosing	1	Belmont STW Ferric storage tank	£0.04m	£0.04m	£0.04m	£0.04m
L	MEICA support	2	Crookham STW MCC[64] kiosk	£1.29m	£0.68m	£1.25m	£1.80m

61 Primary settlement tank
62 Activated sludge plant
63 Rotating biological contactor
64 Motor control centre

13.1.2 Stage 2 – Descriptive assessment

This stage of assessment produced a descriptive assessment of the potential failure modes and their resultant consequences. This output was created through a workshop setting with a panel of experts who understand the site and assets being assessed. Each workshop included a minimum representation of:

- One expert with knowledge of the site’s current operation, performance history and site-specific issues like topography or access.
- One expert with knowledge of the treatment process being discussed, i.e. the use of assets and the hazards associated with operation and failure.
- One expert with knowledge of civil asset deterioration mechanisms and rates.
- One expert with knowledge of our value framework being applied.
- One expert with knowledge of the statutory penalties that might be applied.
- One expert with experience of this workshop process to serve to chair the session[65].

A single expert can serve to fulfil more than one of these roles, but all workshops had all these skills represented and a minimum of three individuals in attendance to ensure an appropriate degree of challenge. The role of these workshop evolved from an initial concept which was performed as a proof-of-concept trial to the actual process that was delivered to complete the remainder of the descriptive assessments:

- The ‘proof-of-concept’ trial was performed as an end-to-end workshop in that the input material was provided but all outputs were blank templates to be completed in the session.
- The actual process was performed as a validation and verification workshop where provisional outputs are provided in the input material for the workshop to review, challenge, amend and approve. This approach was judged to save a material volume of effort and make best use of experts’ availability to complete the whole programme of assessments in the required depth.

The inputs provided to the workshop consisted of a slide pack containing:

- Aerial photographs of the site labelled to identify process stages elements and features such as waterbodies.
- Summary site statistics such as treatment complexity[66] and deployable output.
- Photos of the asset which is the subject of the assessment including commentary from the Atkins survey report. Copies of the report and all accompanying files and phots are also made available to attendees.
- Description of the output required including definitions of terms.

[65] With the exception of the trial workshop where this process was developed.
[66] Following the Ofwat treatment complexity categorisation provided in Regulatory Accounting Guidelines 4.10 for use in Annual Performance Report Table 6A.

- A list of our value framework measures against which the description of consequence should be framed. The full value framework definition document is also made available to attendees.

We used templates for the required output, pre-populated with draft responses (except in the trial workshop), for review, challenge, amend and approve. The pre-populated assessment was produced by a civil or process engineer with domain knowledge and access to the same input materials.

There were three categories for the required outputs of the workshop:

1. Potential failure modes of the asset were identified, with an assessment of the material likelihood of failure within AMP8.
2. For each potential failure mode, the consequences of failure were identified and described for three distinct periods discussed below. These consequences were aligned to our value framework.
   a. Immediate – the period following the initial failure until the immediate incident management exercise is complete[67].
   b. Short-term – the period following the immediate incident management until a temporary solution (such as mobile plant or bypass) or other risk mitigation activity is in place.
   c. Long-term – the period following a temporary solution being in place until a permanent solution is commissioned.
3. Site or asset-specific issues which might impact the assessment of consequence for other assets within the same group are identified and the manner of potential impact is recorded. This assessment must be specific and detailed enough such that it can be used to differentiate the consequence assessment of other assets within the same group. For example, the catastrophic failure of an asset might require the construction of a parallel process stage whilst temporary plant provides a short-term solution. The proximity and availability of land to house the temporary plant and/or construct the parallel process might mean additional costs of land purchase at some sites but not at others, or variable costs for the length of inter-stage pipework.

13.1.3 Stage 3 – Quantified assessment

In this stage, the output from stage 2 describing the consequence of failure was mapped and scored against our value framework so that it was consistent in structure with our business-as-usual cost-benefit assessment. This quantification process has been completed for the example asset from each group which were assessed as part of the workshop process and for each of the potential failure modes identified in the workshop for these assets.

[67] This might include isolating the failed asset, making safe any areas or structures impacted by the failure and clean-up of the failure.

Figure 79 below shows a summary of the quantified assessment of consequence for each of the workshop examples completed for water and wastewater respectively. Assessments for each failure mode considered were provided and each assessment was split in to the three phases (immediate, short-term and long-term), as described in Stage 2 above.

FIGURE 79: QUANTIFIED ASSESSMENT OF CONSEQUENCE (EXAMPLE)

Asset (Group)	Failure mode	Consequence valuation			
		Immediate	Short-term	Long-term	TOTAL
Langford WTW East Reservoir (Raw water reservoir)	External wall collapse	£10.61m	£0.20m	£9.88m	£20.69m
	Internal wall collapse	£0.02m	£0.16m	£9.88m	£10.05m
	Crack and EDD	£0.01m	nil	£9.42m	£9.42m
Honey WTW Hill Clarifiers (Vertical flow treatment tank)	Wall collapse	£0.33m	£0.06m	£0.15m	£0.54m
	Cracked expansion joint	£0.16m	£0.06m	£0.13m	£0.34m
Lumley WTW RGF[68] (Vertical flow treatment tank)	Cracked expansion joint	£0.27m	£0.06m	£0.24m	£0.58m
Hanningfield WTW Ozone Dosing Building (Building – process)	Severe water ingress	£1.66m	£0.79m	£0.46m	£2.90m
Ormesby WTW SSF 5 (Slow sand filters)	Cracking of wall / base	£9.90m	£0.22m	£0.65m	£10.77m
	Slipped embankment	£1.18m	£0.19m	£0.65m	£2.11m
Walpole WTW TWS[69] tank (Treated water storage)	Expansion of cracks	£0.05m	£0.01m	£0.41m	£0.47m
	Water ingress – roof	£0.24m	£0.01m	£0.22m	£0.47m

Asset (Group)	Failure mode	Consequence valuation			
		Immediate	Short-term	Long-term	TOTAL
Consett STW Storm Tank 1 (Storm tank)	External wall failure	£0.07m	£0.15m	£0.43m	£0.65m
Consett STW Detritor (Inlet works)	Failure impacting channel	£0.01m	£0.12m	£0.11m	£0.24m
	Partial failure	£0.01m	£0.09m	£0.08m	£0.19m
Birtley STW PSTs 1-4 (PST)	Cascading failure	£0.05m	£0.75m	£3.26m	£4.06m
	Failure w/o resilience	£0.03m	£0.75m	£3.26m	£4.04m
	Failure	£0.01m	£0.01m	£3.19m	£3.20m
Sedgeletch STW ASP Tanks (ASP)	External wall	£0.09m	£1.87m	£0.23m	£2.20m
	Internal wall	£0.05m	£0.41m	£0.86m	£1.33m
	Ancillaries	£0.03m	£0.10m	£0.08m	£0.21m
Birtley PST Dist. Chamber (Distribution chamber)	Catastrophic	£0.07m	£0.14m	£0.01m	£0.23m
	Sectional	£0.01m	nil	£0.13m	£0.14m
Birtley STW Sludge Tank (Sludge tank)	Structural collapse	£0.05m	£0.26m	£0.27m	£0.58m
Birtley STW TF 5-10 (Trickling filters)	Failure w/o resilience	£0.05m	£0.02m	£13.69m	£13.75m

[68] Rapid Gravity Filter
[69] Treated water storage

For the other assets in the group, we completed a simplified extrapolation process based on the quantification of the workshop example and a suitable scale parameter.

13.1.4 Stage 4 – Validation and verification checks

In this stage, the outputs of stage 3 for all assets were compared and checked for consistency and accuracy. Sources of bias were identified, and adjustments are made to remove them. Discrepancies were identified and resolved.

The process produced a final set of quantified cost-benefit assessments and a log of all changes made to the stage 3 outputs as a result of stage 4 validation and verification. In this analysis for WTW civil assets, there were only simple transposition and formulae errors to correct. In this analysis for STW civil assets, we elected to limit the extrapolation approach when applied to our Bran Sands STW in the Sludge Tank asset group. We had concerns that the unadjusted number over-represented the potential consequence as the scale of the exemplar quantified was so different to Bran Sands. With the adjustment made we feel the consequence assessment better reflects the true potential risk.

Figures 80 and 81 below show for water and wastewater respectively the following for each asset group:

- The scale variable used to extrapolate the consequence value for other assets from the workshop example in Table 13-3 above.
- The 50th percentile capital cost for the programme of work in the asset group to allow a comparison with the consequence values.
- The minimum and maximum consequence values for the asset group.

FIGURE 80: CALCULATION OF CONSEQUENCE VALUES (WATER)

Asset group	Extrapolation	P50 capex (22/23 prices)	Consequence value	
			Minimum	**Maximum**
Raw water reservoir	Deployable output	£10.14m	£18.83m	£41.38m
Vertical flow treatment tank	Deployable output	£5.65m	£10.98m	£17.84m
Building – process	Deployable output	£2.45m	£22.57m	£22.57m
Slow sand filters	Deployable output	£1.78m	£6.33m	£32.32m
Treated water storage	Population served	£1.61m	£0.55m	£0.56m
GAC / iron filter	n/a	£0.87m	Not currently assessed	
General access	n/a	£0.52m	Not currently assessed	
Sludge tanks	n/a	£0.33m	Not currently assessed	
Filter backwash	n/a	£0.59m	Not currently assessed	
Building – stores	n/a	£0.24m	Not currently assessed	
TOTAL		**£24.17m**	**£59.84m**	**£114.67m**

FIGURE 81: CALCULATION OF CONSEQUENCE VALUES (WASTEWATER)

Asset group	Extrapolation	P50 capex (22/23 prices)	Consequence value	
			Minimum	**Maximum**
Storm tank	Flow to full treatment	£4.91m	£8.90m	£8.90m
Inlet works	Flow to full treatment	£2.72m	£1.07m	£1.39m
PST	Dry weather flow	£17.53m	£33.18m	£41.97m
ASP	Dry weather flow	£11.69m	£8.66m	£90.19m
Distribution chamber	Dry weather flow	£0.98m	£92.51m	£92.51m
Sludge tank	Population equivalent	£2.74m	£15.74m	£15.74m
Trickling filter	Dry weather flow	£57.57m	£1.13m	£1.85m
Sludge digester	n/a	£0.38m	Not currently assessed	
Pumping station	n/a	£0.19m	Not currently assessed	
Treatment – other	n/a	£1.55m	Not currently assessed	
General access	n/a	£0.38m	Not currently assessed	
Building	n/a	£0.36m	Not currently assessed	
Humus tank	n/a	£0.24m	Not currently assessed	
Chemical dosing	n/a	£0.04m	Not currently assessed	
MEICA support	n/a	£1.29m	Not currently assessed	
TOTAL		**£102.6m**	**£161.18m**	**£252.56m**

13.1.5 Illustrative case study

This case study illustrates the process described above using the example of the Sedgeletch STW activated sludge plant (ASP) aeration tanks.

Sedgeletch STW is an activated sludge works in Houghton le Spring, with a PE of 51,589 and has an ammonia consent of 3.0mg/l. The condition survey showed the ASP tanks to be in condition grade 4a. As outlined above, Sedgeletch STW underwent a Stage 2 descriptive assessment applying the principles as outlined as above. This was through a workshop process with the aim of recording a description of the potential consequences of failing to repair assets on AMP8.

The workshop was attended by experts from the Wastewater Compliance Team, the Wastewater Strategic Planning Team and the Asset Intelligence Team and a highly experienced Wastewater Operations Technician.

The workshop utilised the following outputs as shown below and the visuals were taken from site as shown below in Figure 829:

Sedgeletch STW: Activated Sludge Plant Aeration Tanks - 4a

“The cast in situ/buried concrete ASP tanks are in an average to poor condition. Significant spalling has occurred to the corner of the cantilever walkway resulting in the exposure of steel reinforcement. Sealant at the middle movement is in very poor condition and all other joints across the structure are in a poor condition and showing signs of degradation and is even missing in places. The movement joint has opened up significantly and requires further investigation. All handrailing is degrading and requires repainting.” (Taken from Condition Survey)

FIGURE 829: WORKSHOP MATERIALS TAKEN FROM SEDGELETCH CONDITION SURVEY

The outputs captured at the workshop, discussing one of the potential failure modes (an external wall failure) are shown in Figure 83 overleaf.

FIGURE 832: EXAMPLE DESCRIPTIVE ASSESSMENT FROM SEDGELETCH STW CONSEQUENCE ANALYSIS

Asset and Asset Grade Condition [4a or 4b]	Potential Failure mode?	Immediate impact	Short Term Impact	Short Term Mitigations?	Long Term impact	Long Term Solution	Comments
ASP Lanes	Catastrophic failure – structural – external wall failure	Majority is underground level – top level of water escaping. Discharge onto road access and site drainage If lower than outlet/overflow weir will discharge through crack – shut the penstock Alarm identified circa 16 hours. Unlikely to hydraulically run the site on 1 single ASP lane. Ammonia consent failure – EPA/Discharge compliance issue	Spill to clean up H&S Significant OPEX costs	Require temporary SAFs Overpumping requirements 3-7 days to install	Continuation of Short-Term impacts	Full draindown of both lanes. Full temporary SAF Replace and refurb 6-18 months	At sites there is a mix between above ground and below ground PSTs Can't use nitrifying filters – a lot of work to get up and running Majority in combined structure form, Browney & Aycliffe separate lanes

Stage 3 of the consequence assessment process quantifies the descriptive outputs from the phase 2 by applying our value framework. Engineering judgement was applied for cost avoidance elements of the value framework where manual input is required. The results of the consequence quantification are summarised in Figure 84 below.

FIGURE 843: RESULTS OF CONSEQUENCE QUANTIFICATION

Impact *Describe the impact*	Descriptive *(How certain is the impact to occur)*	Estimate *(estimated % likelihood)*	Severity *(Based on Copperleaf Value Model or Engineering Judgement where applicable)*	Severity Value *(from Value Model or other)*	Total Cost *(Estimate* Severity Value)*	Comments/Assumptions
			Immediate Impact			
Health and Safety (VM_33)	Low	10%	Potential and Actual Prosecution Level C	£300,000	£30,000	[1] The ASP structure projects above ground level but majority of lane is below ground. [2] The probability of Staff being on the cantilevered / peripheral walkway when collapse occurs is low but not zero. The consequences for any Operative so caught are serious - crushing by concrete, immersion in tank / possible drowning if ASP still aerating wastewater.
Disruption to treatment process (1) Shut inlet (?) penstock to isolate tank. (2) Site cannot be hydraulicly run with only 1 ASP lane. (3) Ammonia consent failure - EPA / Discharge compliance issue.	Certain	100%	Isolated Upper Tier Failure (VM_23)	£52,896.61	£52,896.61	[1] VM_23 Used from Copperleaf
Initial pollution / spill following collapse - (VM_20) (1) The majority of tank below ground level. Only top layer (depth?) of water escaping. (2) Immediate discharge onto road and site drainage. (3) Alarm identified circa 16 hours.	Moderate-Certain	70%	Major or Significant Impact Cat (1 or 2)	£17,065.11	£11,946	[1] Assumed that road / site drainage discharges directly to watercourse / external drainage. [2] Discharge from tank may run for several hours.
			Short-term Impact			

Clean up of initial Spill (H&S issue)	Certain	100%		£1,200	£1,200	[1] Jetvac system (or other needed) + staff costs [2] based off cost for spill clean-up at other STWs
Temporary Treatment - (1) Hire of Pumps and other pump ancillary equipment - e.g. generators? (Overpumping)	Certain	100%	[1] Assume 8 No. x pumps = £400/day	£218,800	£218,800	[1] Engineering Judgement [2] External hire for pumps: 1 - 2 days for pumps to be sourced and brought to site. [3] Temporary overpumping required until ASP repairs completed. This may take 6-18 months. Assume full 18 months.
Temporary Treatment - (2) Hire of several SAF units to provide temporary treatment	Certain	100%	[1] Assume 8 No. SAF = £1600/day	£875,200	£875,200	[1] The number of SAFs required are likely to be significant i.e. not 1 or 2 since Sedgeletch approx pop. 51,589, DWF 131.25lt/s. [2] Temporary treatment required until ASP repairs completed. This may take 6-18months. Assume full 18 months. [3] no guarantee temporary fix can restore STW performance
Temporary Treatment - (1) Additional temporary works e.g. hard standing for SAF units.	Certain	100%	[1] Assume £10,000 hardstanding (material/labour/plant)	£10,000	£10,000	[1] Assume one-off costs [2] Assume it takes 3-7days as a minimum to fully install [3] Engineering Judgement
Temporary Treatment - Cost of integrating pumps / SAFs with existing site telemetry.	Certain	100%	[1] Assume £20,000	£20,000	£20,000	[1] One-off cost [2] Engineering Judgement
Temporary Treatment Opex Costs including - (1) Additional employee time to monitor / maintain temporary arrangement. (2) Energy costs for both pumps and SAFs.	Certain	100%	[1] 1 x employees say 4Hrs/day () [2] Pumps Fuel cost £250/d [3] SAF power cost £1000/d	£749,390	£749,390	[1] Engineering Judgement [2] Assumed Duration of repair/need for temporary works is 18 months
Long-Term Impact						

Cost to Repair - rebuild structure and return to original specification - (1) Will require full drain down of both lanes for replace/repair duration, which could be up to 18months. Temporary treatment will also be required for this duration.	Certain	100%	Cost as "Worst-Case" Scenario from Options Assessed and Costed for Sedgeletch	£210,830	£210,830	[1] Complete rebuild of structure and replacement of internal diffusers / external pipework etc. [2] Assume that the temporary treatment plant and pumping is included in the Short-Term Impact Section
Regulatory failure due to temporary plant (VM_39) - (1) It may be difficult to achieve regulatory compliance with SAFs leading to Consent failures and reputational damage.	Median	50%	Major or Significant Impact Cat (1 or 2)	£38,115.87	£19,058	[1] Level of fine is estimate. Will EA treat collapse as negligence and ramp up fine according? [2] Long term impact is Works is considered "At Risk" [3] Scored using Value Model
			Total Consequence Valuation	**£2,199,320**		