Dŵr Cymru
Welsh Water

WSH51-CW00 –

Safe and High-Quality Tap Water

Contents

1 Safe and High-Quality Tap Water

1.1 Background and purpose of this document

This document describes Welsh Water's plan for safe and high-quality drinking water: where we are optimising results and making savings from base-funded activities and where we need enhanced investment. It shows the overall context and interrelationship of our proposed enhancements for AMP8 and demonstrates how each case addresses specific challenges and contributes to our overarching objectives.

While the WSH01 Long Term Delivery Strategy outlines our comprehensive long-term vision, and the PR24 Business Plan summarises our AMP8 approach, this document provides connecting narrative to the enhancement cases. Its purpose is to show coherence where the relationships between needs and solutions are not directly one-to-one but rather intertwined, with some solutions meeting multiple needs and/or combining with other solutions to greater effect.

It is intended to be read by anyone delving into the detail of any of the proposed enhancement cases for a more comprehensive grasp of how they align, complement, and reinforce each other.

Firstly, the document reflects the high-level steers we have received through customer and stakeholder consultation and our own WSH01 Long Term Delivery Strategy. These are covered in greater detail in other parts of this submission: PR24 Forum High-Level Steers (Stepping up to the Challenge: Business Plan 2025-30 (Section 2.3) and WSH30 – Customer Engagement and Research. They have informed our Performance Commitments for 2025-2030 (AMP8) and beyond.

The second half of the document describes the challenges to drinking water safety and quality, the range of options we have considered to meet them, and the outputs of our optioneering process. Highlighted examples of chosen schemes are given and the evidence for enhancement cases is presented with supporting detail provided in the associated enhancement cases.

Ensuring the safety of drinking water involves monitoring and treating the water to remove contaminants and protect public health. It also involves preventing pollution of water sources and implementing regulations and policies to protect water quality.

However, water acceptability goes beyond safety alone. While our water is unquestionably safe to drink, we also strive to deliver water that meets our customers' expectations in terms of clarity, colour, taste and odour.

To sustainably supply safe and high-quality drinking water in the long term, we need to:

- Maintain current standards of drinking water safety and quality
- Adapt and respond to emerging challenges, such as the effects of more frequent extreme weather events
- Meet new and more stringent regulatory requirements
- Work over time to reduce the underlying factors in the environment that increase the cost of treating water to a high standard, such as deterioration in the quality of raw water

It will not be possible to meet all these needs in AMP8 just by operating and maintaining our assets at their current levels of service and refining and innovating how we operate. Additional 'enhancement' expenditure will be required to meet these needs. Through longlisting, shortlisting and thoroughly testing our options, our approach to investment, as detailed in Welsh Water's WSH50-IP00 Our Approach to Investment Planning, is designed to identify the blend of base and enhancement expenditure that will result in the optimal 'low-regret' set of interventions.

It will be seen how the largest area of investment in water quality in AMP8 is in the distribution network. This is an area where the most significant gains can be made quickly and measurably. Investments in raw

water sources and treatment have a longer-term impact, or not sufficient measurable impact, on our performance commitments in AMP8 but are also essential to meet legislative targets, address underlying low-likelihood and high-consequence risks and deliver our long-term strategy. In these cases, customers are protected through a package of Price Control Deliverables (PCDs).

This document should be read in conjunction with its associated enhancement cases, which offer a structured treatment of the criteria for enhanced funding:

- WSH53-CW01 - Improving Raw Water Quality in Catchments through Green Solutions
- WSH54-CW02 - Improving Acceptability of Tap Water - Networks
- WSH55-CW03 - Improving Quality of Tap Water - Treatment Works
- WSH52-CW04 - Working towards a Lead-Free Wales

1.2 Our Customers' Expectations

The customer research conducted for the PR24 business plan followed a framework for customer insight that was agreed with our Independent Challenge Group, guided by Ofwat's customer engagement policy for PR24. It followed best-practice market research standards. The structured programme of customer engagement and the findings from the research are detailed in Our approach to customer engagement is set out in Stepping up to the Challenge: Business Plan 2025-30 (Section 2.2).

Relevant insights on water quality are summarised below:

In general, our customers express satisfaction with the drinking water we supply. It is important to note that customers generally make a distinction between factors such as discolouration, unusual taste or smell on the one hand, and the safety of tap water for drinking purposes on the other. As long as the water is safe to drink, these aesthetic aspects are seen by customers as less of a priority for investment compared to other areas.

Figure 1: What do customers say about reducing incidents of tap water being discoloured, or having an unusual taste or smell? (Informing PR24: A Research Report - August 2021)

In the Phase 2 quantitative research, a significant portion of the total sample (41%) considered investment in safe and high-quality drinking water as a higher priority than keeping bills low, and 37% ranked it of equal importance. This indicates that customers recognize the importance of maintaining and improving tap water quality, even if it comes at a slightly higher cost.

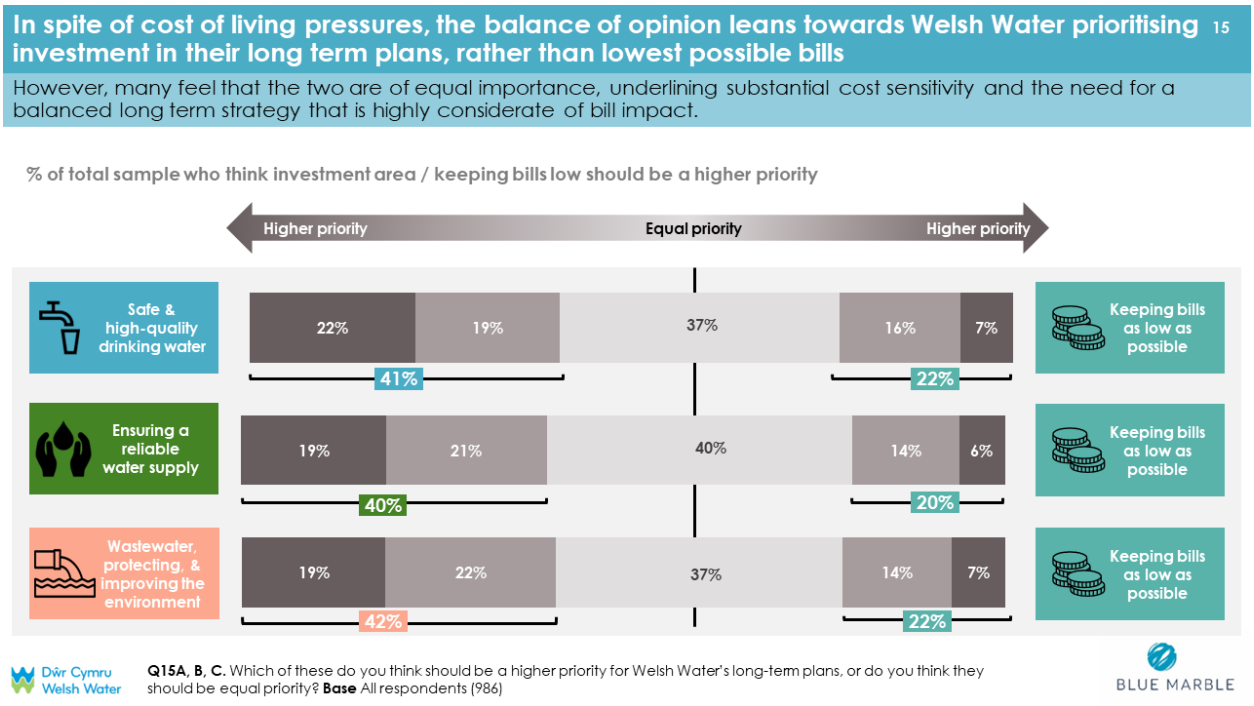

Figure 2: How customers prioritise investment areas against keeping bills as low as possible

Furthermore, in qualitative surveys, customers rarely reported problems related to water safety, emphasizing that any concerns were mostly cosmetic. This perception of water quality as generally satisfactory contributes to its lower importance to our customers in terms of investment priorities.

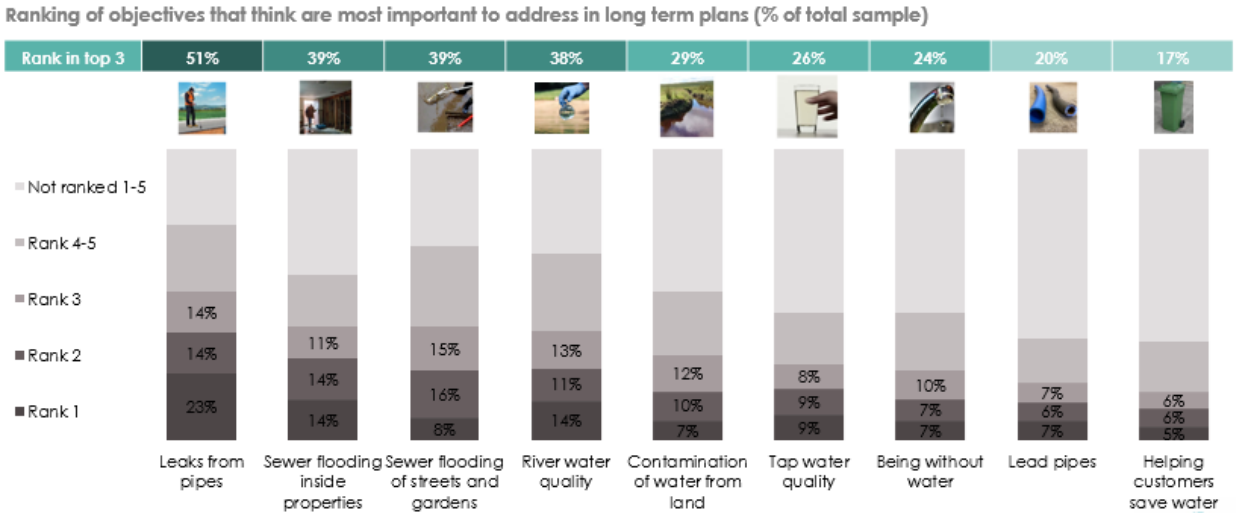

Figure 3: how customers prioritise water-quality and other investments

Results from acceptability and affordability testing show that some customers were disappointed that Welsh Water are underperforming in the rate of customer contacts for water-quality issues, although the measure was felt to be subjective. However, the 2030 target of 1 contact per 1,000 customers was found to be acceptable.

On the specific issue of lead pipes (part of water safety), customers had mixed views. It is understood by most (though not all) of our customers that lead in drinking water is potentially harmful, particularly to

children. This is a definite concern for many customers and somewhat unexpected, as they perceive lead to no longer be in the network.

> *"I wouldn't have thought there was any lead left in our water piping — this is really surprising!" — Male, 59*
>
> *"If the lead in the pipes was harming people, we'd know about it. That we haven't heard this means it can't be that urgent to fix, and investment could be better prioritized." — Male, 21*

This immediate level of concern is why customers initially want removal of lead prioritised in future investment. However, when they learn that it is only in the connection between the mains and the stop tap that some lead persists, and that part of this is their responsibility, this feels like less of a priority for the water company to resolve. In our Phase 2 research, it was the second-least important area (though they still want Welsh Water to make customers aware of the fact).

> *"Lead is quite dangerous — I'd expect Welsh Water to find the funding to fix this wherever it's a problem. People shouldn't be getting sick from their water." — Female, 42*
>
> *"I wouldn't expect my bill to go up so that Welsh Water could fix the piping that's part of someone else's house. That should be dealt with individually." — Female, 34*

Many of our customers seem accepting of an element of shared responsibility between individual households and the water company here rather than a universal bill increase.

> *“The shared responsibility will make it harder for Welsh Water to make all the necessary changes and could make the process drag out as a result." — Female, 78*
>
> *"It does seem quite dangerous, so it is a fairly high priority, but if we are saying householders are partly responsible, then it shouldn't just be on Welsh Water to fix this." — Male, 26*

1.3 What our stakeholders have told us

Our long-term outcomes are collaboratively developed with the PR24 Forum, which is chaired by the Welsh Government and includes all our key regulators as well as benefitting from the input of customers and wider stakeholders.

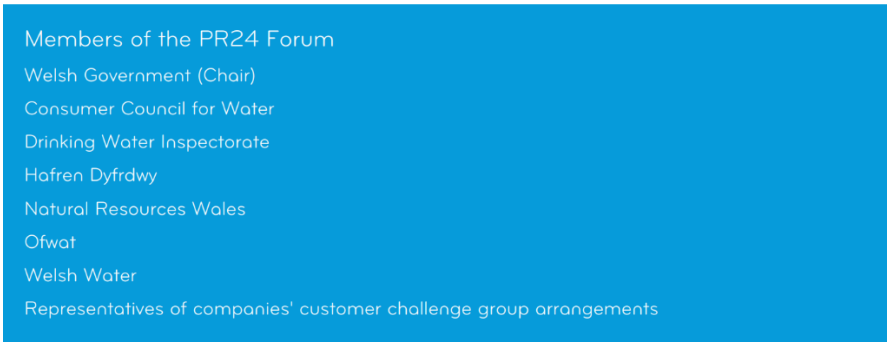

Figure 4: Members of the PR24 Forum

The forum’s processes and conclusions are outlined in Our approach to customer engagement is set out in Stepping up to the Challenge: Business Plan 2025-30 (Section 2.3).

The PR24 Forum has issued strategic directions for water companies and Ofwat, as well as addressing challenges and priorities for the water sector. In respect to drinking water quality, it has stated:

- Companies should provide assurance on how they are assessing and managing risks associated to their assets, from network to natural assets (such as the catchments that support raw water supply).

- We expect companies to improve their asset health to address the risks to drinking water quality and compliance.
- We expect Welsh Water to improve its performance on key service measures in the short-term where it is performing poorly on a comparative basis.

1.4 Regulatory and legislative requirements

In addition to customer and stakeholder perspectives, there are regulatory drivers that are concerned with water quality.

1.4.1 Drinking Water Inspectorate (DWI)

The DWI sets standards, conducts inspections, and enforces compliance with drinking water regulations. Water companies must meet the requirements set by the DWI to ensure the delivery of safe and clean drinking water.

For example, on the specific issue of lead pipes, the DWI's PR24 guidance position is as follows:

"Reducing the risk of lead in drinking water should remain a priority. Companies should be ambitious in their long-term lead strategies and continue to plan and invest in the reduction of lead exposure through drinking water. Pilot trials should inform wholescale lead pipe replacement programmes and consider any future reduction in plumbosolvency control. Companies should use the findings of the report *Long-term Strategies to Reduce Lead Exposure from Drinking Water* and any findings from Green Recovery lead trial schemes in their plans." (*Price review process - Drinking Water Inspectorate (dwi.gov.uk))*

Outside of the PR24 Forum, we have engaged extensively with the DWI over our plans for AMP8 and through to 2050 regarding water quality. The Drinking Water Inspectorate supports the delivery of the following schemes to secure or maintain drinking water quality as confirmed in the following letters issued by DWI:

Table 1: DWI letters supporting water quality schemes

Scheme	Letter Reference	Comments
DWR1 - Cefn Dryscoed Raw Water Deterioration, discolouration and manganese	DWR1	Caveats: The risk of occurrence of taste and odour forming compounds in the raw water should be investigated as part of this work and, if required, mitigation delivered Timescale: Within AMP8 Cost: £12.505M (capex), £0.592M/year (OpEx) Legal Instrument Required: Regulation 28(4) Notice

Scheme	Letter Reference	Comments
DWR2 - Regulation 26 Ultraviolet Schemes - Disinfection and Cryptosporidium	DWR2	Caveats: No specific caveats Timescale: Within AMP8 Cost: Bretton £2.345M (capex) £0.100M (OpEx) Broomy Hill £3.032M (capex) £0.234M (OpEx) Mayhill £1.293M (capex) £0.040(OpEx) Whitbourne £1.412M (capex) £0.164M (OpEx) Legal Instrument Required: Regulation 28(4) Notice
DWR4 - Capel Curig - THMs and Disinfection Byproducts	DWR4	Caveats: No specific caveats Timescale: Within AMP8 Cost: £4.668M (capex), £0.1M /year (OpEx) Legal Instrument Required: Regulation 28(4) Notice
DWR5 - Increased GAC capacity at Mayhill	DWR5	Caveats: No specific caveats Timescale: Within AMP8 Cost: £2.919M (capex) Legal Instrument Required: Regulation 28(4) Notice – this will be covered by the notice currently being negotiated (DWR-2023-00003)
DWR6 - Overall Acceptability Performance	DWR6	Caveats: None Timescale: Within AMP8 Cost: £118.421M (capex) Legal Instrument Required: Regulation 28(4) Notice
DWR7 – Towards a Lead Free Wales	DWR7	Caveats: None Timescale: expected to be within AMP8 Cost; £14.804M (capex) Commended for Support

Scheme	Letter Reference	Comments
DWR8 – PFAS Strategy	DWR8	Caveats: None Timescale: expected to be within AMP8 Commended for Support
DWR9 – Safeguarding Clean Drinking Water Through Catchment Management	DWR9	Caveats: None Timescale: expected to be within AMP8 Cost: £26.553M (capex) Commended for Support

Where legal instruments are in place, we are legally bound to deliver the proposed schemes or face fines.

1.5 Long Term Ambitions

1.5.1 Long Term Delivery Strategy

Our WSH01 Long Term Delivery Strategy sets out the 2050 outcomes that have been agreed with the PR24 Forum along with the interventions needed to achieve those outcomes. It articulates how we will accumulate successful outcomes in each of the 5-year planning periods to reach our goals in a range of plausible futures. These have been informed by and are consistent within Welsh Water 2050, published in 2018 and revised in 2022, which set out our broad vision, priorities and direction of travel for the coming decades and included the following long-term outcomes affecting tap water quality:

- Safeguarding Clean Drinking Water Through Catchment Management
- Achieving Acceptable Water Quality for All our customers
- Towards a Lead-Free Wales

The full Long Term Delivery Strategy forms part of this business plan submission and can be read in the WSH01 Long Term Delivery Strategy document.

Interventions included in our ‘low regrets’ AMP8 plan, in respect to tap water quality, will significantly contribute to preventing deterioration in this measure and driving down the number of customer contacts for taste, odour and colour towards our 2050 outcome of 0.5 per 1,000 customers.

Additionally, as part of the wider strategy on tap water quality, we will be reducing the number of Safeguard Zones for raw water quality from 18 to 13 on our path to having only 5 remaining by 2050. We are also replacing 7,500 lead pipes, bringing us closer to the 2050 target of replacing 100,000 lead pipes over the next 25 years (see Table 2).

Table 2: Planned outcomes to 2050:

Performance against Outcome					
Outcome	AMP8	AMP9	AMP10	AMP11	AMP12
Tap Water Quality Compliance Index	0	0	0	0	0
Acceptability of Water (Customer contacts per 1000)	1.00	0.88	0.75	0.63	0.50
Protecting Raw Water Quality (number of SgZs recovered)	13	9	5	5	5
Cumulative number of Lead pipes replaced since the start of AMP8	7,500	30,625	53,750	76,875	100,000

1.6 Efficiency challenge

As described in WSH50-IP00 Our Approach to Investment Planning (Section 5), on recommendation from the Executive Team, our Board has set ambitions in our PR24 Plan and Long Term Delivery Strategy in relation both to outcomes (see Table *2*) and efficiency of expenditure. The target set by the Board on the planned AMP8 CapEx investment in tap water quality amounts to £153M.

It is important to note that **all the costs mentioned in this document, the data tables and other parts of the PR24 Plan** and Long Term Delivery Strategy **already reflect the efficiency challenge posed by the Board**. This challenge represents an ambitious **28.6%** efficiency in AMP8 CapEx investment in tap water quality (on top of the efficiencies already identified by the business during the development of the business plan) and ensures best value for customers.

2 Performance Commitments

In relation to Water Quality, there are two common regulatory performance commitments (PCs), and one other commitment in our plan, in relation to lead in drinking water, which takes the form of a 'price control deliverable'. We also include a price control deliverable in relation to our work to monitor and control raw water quality in catchments.

The common industry PCs are

- **Compliance Risk Index (CRI)**: a DWI measure reflecting the risk resulting from compliance failures in the quality of treated water.
- **Customer contacts about water taste, odour and colour:** the number of times we are contacted by our customers due to the taste and odour of drinking water or because the drinking water is not clear, reported per 1,000 population

2.1 Performance Commitment 1: Compliance Risk Index (CRI)

The Compliance Risk Index (CRI) is a measure designed to illustrate the risk arising from treated water compliance failures. It aligns with the risk-based approach to regulation of water supplies used by the DWI and is based on the provisions of the Water Industry Act 1991.

CRI is calculated based on analytical results generated from regulatory samples taken at water treatment works, service reservoirs and water supply zones. A CRI score is calculated for every individual compliance failure. The individual CRI scores for each compliance failure reported during a given year are added up to determine a company's annual CRI.

2.1.1 Past performance, trends and targets

CRI (Compliance Risk Index) is a critical compliance measure, and our goal is to achieve zero compliance failures each year.

Achieving a CRI score of zero is exceptionally challenging in practice due to the complex nature of water supply systems and the numerous parameters that need to be monitored and controlled. Even with rigorous water quality management practices, it can be difficult to prevent occasional compliance failures and, typically, all large water companies will have CRI scores above zero (see Figure *5*), taken from the DWI Annual Report for Wales 2022 which shows our relative position to the rest of the industry. Ofwat established a 'deadband' of 2.0 at PR19, above which companies incur penalties during AMP7.

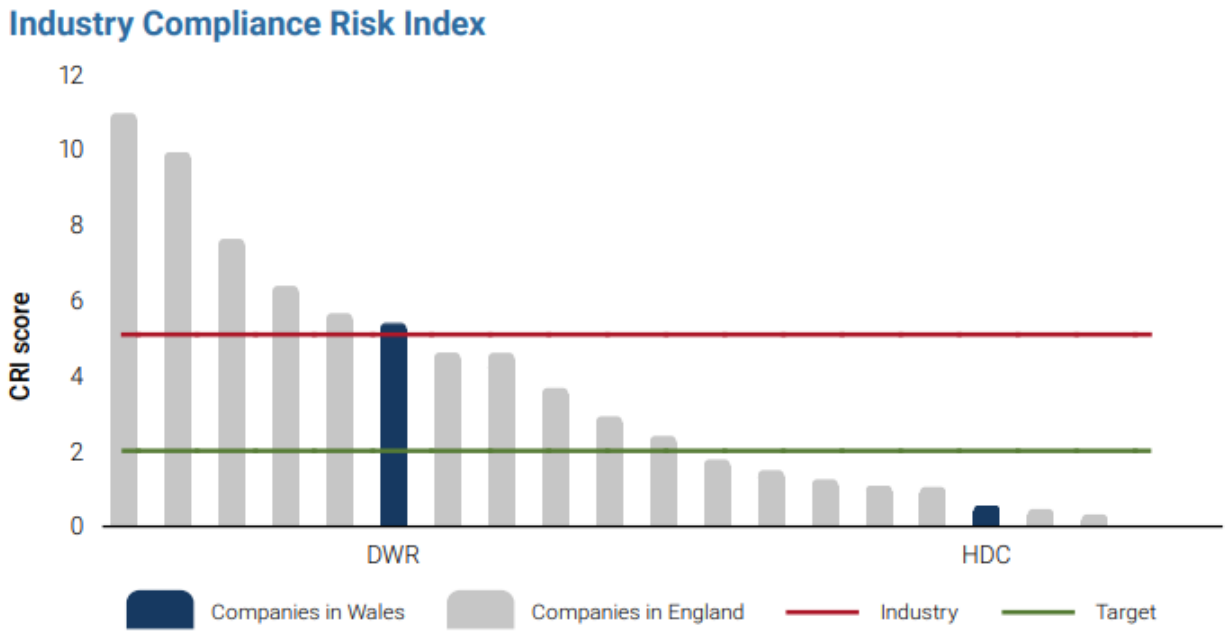

Figure 5: Industry Compliance Risk Index by company in 2022

CRI is calculated based on three main factors: Parameter Score, Assessment Score, and Impact Score. These cover the significance of parameter failures, the cause of failures, the company's investigative efforts, mitigation measures, and the number of consumers affected.

The PR24 Forum Strategic Steers for CRI expect Welsh Water to improve its performance and bring it at least in line with the average of other water companies by 2025 while seeking further long-term improvements.

At PR19, a CRI score of 4.5 was determined to be an achievable standard by the end of AMP7. However, there have been increases in the CRI score in 21/22 and 22/23, primarily due to isolated coliform issues at Felindre and Pontsticill. Even though they are isolated events, these single failures can significantly impact the CRI score: in these cases, because of the weight given to bacteriological failures and the sheer number of customers served by the treatment works (the parameter score being, in a sense, multiplied by the number of consumers affected).

During AMP7, in 2021, the DWI introduced a 'multiplier' affecting water quality zones where DWI enforcement notices were already in place. This was not accounted for at the start of the period and has also affected our ability to achieve the CRI of 4.5.

Welsh Water contends with a 'background' effect from the condition of our network while we are on a trajectory to improve it as quickly as possible. In this context, a high proportion (consistently about one third) of our CRI is resulting from pre-existing issues we are unable to fix quickly, requiring intensive investment over multiple AMPs. The company has been transparent about the issues causing poor CRI performance and is fully cooperating with the DWI while undertaking root cause analysis to confirm the improvements required on a 'source to tap' basis.

Table 3: Welsh Water's CRI performance (actual 2020-2023, targeted 2023-2025)

Year	20/21	21/22	22/23	23/24	24/25
CRI Score	4.17	6.41	5.62	0.0	0.0

Finally, it is notable that while CRI is essentially a measurement of the safety of water in terms of public health, customer contacts (See Section 2.2 below) are a measure of acceptability. However, in the cases

of failures relating to iron and manganese, both scores tend to be negatively affected, which effectively multiplies the impact of these challenges.

2.2 Performance Commitment 2: Customer contacts about taste, odour and colour

Customer acceptability is an important aspect of water quality, and it is measured by the number of customer contacts received by Welsh Water from within its supply area. These contacts are categorized according to the specific criteria defined by the DWI.

Contacts from customers regarding water quality are usually concerned with:

- Discolouration: Discolouration can occur for several reasons, such as sediment, rust, or other particulate matter in the water distribution system. Welsh Water receives a significant percentage of customer contacts related to discolouration issues, including cases of brown, black or orange (BBO) water.
- Taste and Odour: Customers may also contact Welsh Water regarding the taste and odour of their tap water. This category focuses on the subjective perception of the water's taste and smell. Issues related to taste and odour can arise from factors such as chlorine levels, organic compounds, or the presence of certain minerals.

The current rates of customer contacts per 1,000 about the taste, odour and colour of tap water is 2.35 (total) of which 1.67 is due to colour (about 71%), and 0.68 (about 29%) due to taste or smell.

2.2.1 Past performance, trends and targets

We currently have a contact rate of 2.35 and are on track to achieve our PR19 target of 1.58 contacts per 1,000 customers by the end of AMP7:

Table 4: Welsh Water's customer contacts performance (actual 2020-2023, targeted 2023-2025)

Year	20/21	21/22	22/23	23/24	24/25
AoW contacts per 1,000 customers	2.7	2.44	2.35	2.02	1.75

The table above shows the actual customer contacts from 2020 to 2023 and the targets we expect to achieve 2023 to 2025. The step improvement in the last two years of AMP7 can be attributed to tangible gains from our Network Intervention Programme of targeted replacement of cast iron mains, cleansing of 'preferred materials' mains and other operational interventions. Although delayed, due to the effects of COVID-19 that have affected many aspects of our operations, this has shown promise and is gradually coming into effect.

Increased efforts to regain momentum in the next two years encompass both base maintenance and the secondary benefits derived from various investments in our network. We are beginning to witness the positive impacts of these investments on our overall performance.

Welsh Water's long-term ambition is to achieve a customer contact rate of 0.5 per 1,000 customers by 2050:

Table 5: Welsh Water's targeted performance on customer contacts - AMPs 8 to 13

Year	AMP8	AMP9	AMP10	AMP11	AMP12
AoW contacts per 1,000 customers	1.00	0.88	0.75	0.63	0.50

Our ambition is supported by DWI notice DWR-2022-00004 Discolouration, which sets targets on contacts for BBO discolouration in AMPs 7 to 9:

Table 6: Targets for BBO contacts up to AMP9

	Welsh Water's Ambitions on Total AoW contacts per 1,000 customers [A]	Targets agreed with DWI on BBO-only AoW contacts per 1,000 customers [B]	Inferred targets on non-BBO contacts per 1,000 customers [C = A – B]
Current Position (22/23)	2.35	1.67	0.68
End of AMP7 Target	1.75	0.90	0.68
End of AMP8 Target	1.00	0.70	0.30
End of AMP9 Target	0.88	0.40	0.30

3 Meeting the challenges to water quality

There are challenges to water quality and opportunities to maintain and enhance water quality at different points in the water cycle – put simply these points are

- Catchments – where our raw water is collected
- Treatment works – Where the raw water is treated to Potable standard
- Distribution Network – where the water is storage and conveyed to our customers

To meet our targets in the long term, Welsh Water is continually adapting to challenges that emerge in each area but with an overarching consideration of the whole system – source to tap. Risks in one part of the system can often be more cost-effectively mitigated by intervening in another part of the system, so it is important to understand challenges in their overall context. Generally, the further upstream a problem can be resolved, the more cost effective it is.

In the catchment areas, a proactive strategy involving close collaboration with lawmakers, policymakers, and regulators is needed to, for example, preserve the integrity of Mega-Catchment initiatives and secure raw water sources by preventing illegal dumping. As emerging risks like climate change and land use evolve, more comprehensive interventions become necessary, including potential source relocation or third-party collaborations to minimize surface runoff into vulnerable zones. Here we have less control, and the effects of interventions can be difficult to model.

Risks not addressed in the catchments travel on down to treatment works, where we have further opportunities to enhance the quality of raw water through, for example, exploring scientific dosing approaches, ensuring the integrity of existing treatment processes, and considering the replacement or improvement of treatment works and service reservoirs when necessary. Here we have a greater level of control.

Finally, in the distribution network, we again depend to some extent on wider engagement with customers and stakeholders. Proactive customer engagement is essential, with measures in place to inform customers about potential changes in the colour, taste, or odour of their drinking water, ensuring transparency regarding safety, root causes, and solutions. At the same time, we can optimise the network by measures such as right-sizing pipes, using innovative solutions to treat discolouration, and increasing redundancy for more frequent flushing without service disruptions. Here, as well as addressing residual risks not removed at the catchment or treatment works, we need to address the challenge introduced by the presence of lead pipes in the network.

In developing a comprehensive long-list of options to meet water supply challenges, we have considered:

- Whether there are ways the challenge can be eliminated, reduced or delayed so it is no longer causing a risk
- How we can manage risks by maintaining effective controls that are already in place
- What enhancements to existing or addition of new resources are needed to meet the challenge and future risks

Solution Category	Example	Certainty of Success
Eliminate, reduce or delay the need for change	Manage demand, influence future legislation	Low/Medium
Maintain the effective risk controls already in place	Maintain, replace the existing asset like-for-like, or mothball/dispose of the existing asset or service	Medium/High
Enhance existing resources or add new resources	Upgrade an existing asset, create/acquire a new asset or service	High

Figure 6: Hierarchy of solutions

This hierarchical approach makes sure that we consider wider approaches that are beyond the asset base alone, as well as building a good understanding of how we can maximise the potential of our existing services before needing enhanced schemes.

This section will explore

1. The challenges that arise in each of the three areas of the water supply pathway (Catchments, treatment works, and the distribution network) and some of the solution options considered
2. How we will maintain and improve our performance through base maintenance
3. The interventions that we are proposing in each of the three areas for AMP8 and the impacts that they will have on performance.

Some case studies will be highlighted within the discussion, and links will be provided to relevant detailed enhancement cases at the end of each section.

Some of the challenges outlined are ongoing risks that can be met through our base -funded activities to maintain current service levels. Other challenges represent escalating or emergent risks driven by factors outside of our control. They may therefore call for new or better interventions just to maintain current levels of service or to meet more demanding targets, and consequently require enhanced investment.

3.1 Meeting challenges in catchments

Raw water refers to the water occurring in nature, which is the basic resource from which we abstract our raw supply. It may be in rivers, reservoirs, or groundwater. The quality of raw water affects how much and what type of treatment is needed to make it safe and appealing to customers. It also affects the delivery of treated water to customers' premises because it can have a strong influence on how quality deteriorates through the system and quickly the condition of the pipework deteriorates.

To supply our customers with safe and high-quality drinking water, Welsh Water takes raw water from more than 100 topographically discrete catchments covering a combined area of almost 11,000km^2 in Wales and on the England border. 95% of raw water is derived from surface water catchments (shown in blue in 7). We use major river sources such as the Usk, Wye and Dee as well as upland impounding reservoirs. 5% of our raw water comes from groundwater shallow boreholes and springs (shown in red in Figure *7*).

Figure 7: Welsh Water's surface water catchments

3.1.1 Challenges in our Catchments

Raw water as it naturally occurs, contains impurities that need to be removed before it becomes a safe and high-quality drinking water. These include suspended solids, dissolved minerals, nutrients (nitrogen and phosphorus), organic matter, pathogens and chemical pollutants from runoff. Any of these parameters if not removed effectively would have a negative impact on CRI and our customer's perception of our water. These challenges will only become worse with the effects of climate change and we are seeing this already affect our downstream processes. In the DWI's Chief Inspectors Report (2022) for Wales, he drew a conclusion from three reported events, that our water treatment works were in danger of being overwhelmed by raw water-quality deterioration in our catchments. So, challenges emerging at this point in the water cycle tend to cascade on into the treatment and distribution system.

Regarding our sources of raw water, the following risks need to be addressed:

3.1.1.1 Climate change

Climate change poses a significant challenge to the quality of our raw water. For example, drought and heavy rainfall affect runoff and sedimentation. As weather patterns become more unpredictable and extreme, we anticipate further increased variability in raw water quality. Of particular concern are the three areas outlined below.

Naturally Organic material (NOM): Wet weather can increase the material that runs into our reservoirs and rivers from the environment. This can impact our downstream processes in several ways

- Increased solids loading at our treatment works – testing chemical and physical processes

- Increased disinfection by-product formation – as dissolved organic compounds reacts with chlorine, and
- Increased in pathogen load - challenging disinfection capability at our treatment works.

Increased Algal Activity: Warm and sunny weather creates ideal conditions for algae growth that leading to taste and odour issues that impact our customers. Nutrient run off from farmland and industrial activity can fuel this growth further.

Low levels in our reservoirs and river abstractions: extended dry periods and high demand for water driven by warm weather can lead significantly lower levels in our reservoirs. The water quality that we abstract at these levels can have elevated levels of dissolved metals such as manganese.

3.1.1.2 Other Catchment challenges

Third-party activities

Third-party activities can affect raw water quality and, by extension, CRI and acceptability of water contacts. For example:

- abuse or misuse (such as illegal dumping), leading to ad-hoc negative shocks to raw water quality
- legitimate land management and farming practices leading to risks of cryptosporidium, chemical pollutants from run-off and nutrients (e.g., nitrogen and phosphorus) in the raw water
- Industrial activity in our catchments can also present a risk to water quality.

As an example of the last item, a recent experience at Mayhill WTW resulted in a spike in taste and odour contacts from customers. Mayhill WTW is located on the river Wye which has an extensive catchment of approximately 3,400 km2. A large proportion of the catchment is farmland which brings extensive pollution from chemicals, pesticides and slurry runoff risk. There is also extensive food and chemical manufacturing within the catchment, including within the upstream city of Hereford and in and around Monmouth town. Finally, the River Wye catchment contains a number of major trunk roads including the A470, A40 and M50 motorway. The root cause to the spike in taste and odour contacts looks to have been the result of an organic compounds entering the river locally to Monmouth. This has not historically been an issue within this catchment and has resulted in an assessment of additional treatment options at the works to avoid future events occurring.

Our geology

The geology of the west coast of the UK and Wales in particular, have higher instances of manganese deposits in rocks and soils. Under certain conditions, manganese becomes soluble in water. As a result, much of Welsh Water's raw water is higher in manganese than other parts of the UK. Previous investments, in AMP1 and AMP2, installed manganese removal processes to meet the 50µg/L regulatory standard. We now understand that manganese is a direct contributor to water discolouration when it becomes concentrated at pipe walls and is then mobilised during a sudden flow change. Levels as low as 1µg/L can be seen to have a direct correlation with rates of customer contacts for discolouration.

Figure 8 shows a representation of manganese deposits in stream sediments overlaid with water company boundaries (British Geological Survey). The map clearly shows a difference in manganese concentrations in Wales and western areas compared with other regions where many of these streams will directly feed upland reservoirs but also rivers where there are abstractions and interaction with groundwater sources also. This highlights the additional challenge of manganese removal at treatment works in these areas which have shown to have a direct impact on discolouration and acceptability of water.

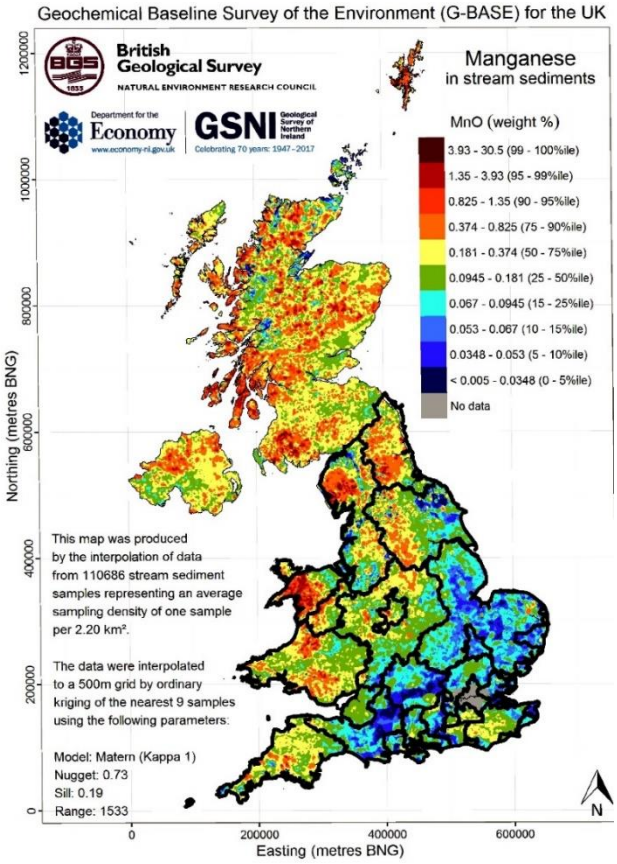

Figure 8 – Manganese in Stream Sediments (British Geological Survey) overlaid with water company boundaries

To add to this, using data available from the DWI, the graph in Figure 9 illustrates a 3 year average of each company's performance for manganese concentration at customer's taps and discolouration. There is a direct correlation between these two metrics, which reinforces our case that manganese removal at water treatment works is particularly important in our overall acceptability strategy. It is clear that this is contributing to the overall performance challenge beyond what asset maintenance may resolve.

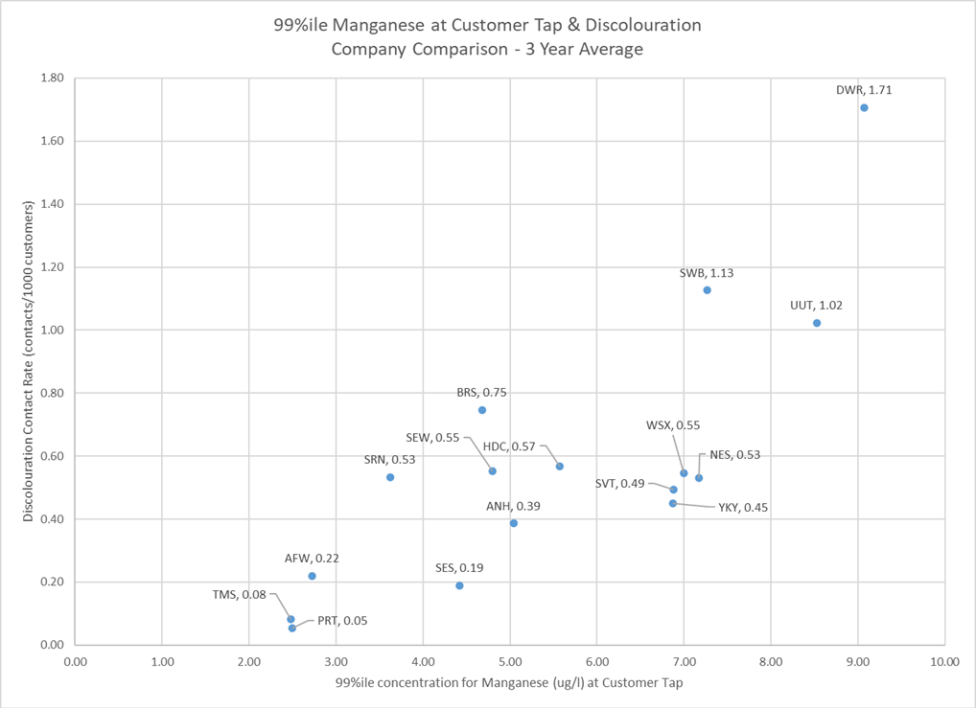

Figure 9 - Graph illustrating the correlation between manganese at customer's taps and discolouration performance

3.1.2 Options to Overcome Challenges in our Catchments

To meet the challenges of raw water quality deterioration, Welsh Water has followed a robust optioneering approach as outlined in WSH50-IP00 Our Approach to Investment Planning. This section highlights the results of our shortlisting, showing where we can optimise from base-funded activities and where we need enhanced investment.

3.1.2.1 Eliminating, reducing or delaying the need for change

Mitigating the influence of climate change:

Efforts to mitigate the influence of climate change on raw water quality align with our Long Term Delivery Strategy (c) and are among the motivations behind our company-wide objectives to decrease carbon emissions. However, it is essential to acknowledge that this approach may not be practical or timely enough to address the imminent impact of climate change on raw water quality during AMP8. Catchment solutions will deliver improvements over a longer period and are an essential part of our Long Term Delivery Strategy.

Influencing the formation of legislation:

We have been assisting Welsh Government with their work on understanding the impact of transposing the Drinking Water Directive into the Wales Water Quality Regulations. Through this engagement, we have been able to agree with Welsh Government and the DWI that there is no need for AMP8 investment in anticipation of the water quality standards in the Drinking Water Directive being transposed.

3.1.2.2 Maintaining the effective risk controls already in place

To ensure the resilience of our safe and high-quality drinking water, even as risks are increasing over time, we must build on the successes already achieved and maintain the effectiveness of risk controls put in place across multiple AMPs.

In AMP8 our base investment will maintain existing risk controls and contribute to our performance in AoW and CRI. Maintaining current performance includes measures such as the management of the Brecon Beacons Mega-Catchment and the upkeep of protective fencing around our raw water sources.

Our catchment management programme also supports the following activities from base:

Existing partnerships and engagement:

Working in collaboration with partners and communities to raise awareness of the importance of safeguarding drinking water supplies both now and for years to come, for example: our WaterSource and PestSmart messaging, supporting partnerships with Wales Young Farmers Club and other educational organisations and setting up collaborative working groups (local SgZ working groups with NRW and BBMC Steering Group).

Estate Management (Base):

Ongoing maintenance of our land estate to meet landlord obligations and to demonstrate best management practices for the protection of drinking water sources, leading by example to enhance our WaterSource messaging with 3rd parties.

3.1.2.3 Enhancing existing or adding new resources

While our current procedures are effective for preserving the current level of risk, these existing measures have limitations when it comes to addressing emerging risks like climate change or alterations in land use that impact our raw water sources.

As Welsh Water own less than 5% of the land within our drinking water catchments, effective controls of risks must encompass people-focussed arrangements, further operational interventions and asset-based solutions. Our catchment management programme supports the following activities:

Risk evaluation:

Understanding the challenges to water quality through monitoring, local knowledge within each catchment and Drinking Water Safety Plans, new for AMP 8 is the challenge posed by PFAS (per- and polyfluoroalkyl substances)

Smart catchments for enhanced water quality monitoring:

Building on our progress to date, our Smart Catchments initiative includes the creation of a 'Digital Twin,' a digital replica of the real-world, to illustrate the intricate relationship between land and water. This technology provides a comprehensive understanding of how these systems are interconnected.

Research and innovation:

Undertaking cutting edge science and novel approaches for developing robust solutions to improve water quality through strategic partnerships with academia

New ways of working and mitigation:

Co-designing solutions with land managers which will deliver benefits for people, water and the environment by;

- Influencing future Government strategic policies for water and environmental protection,

- supporting farmer led groups to trial new technologies for more informed decision-making (e.g. Beacons Water Group),
- land restoration and management improvements in peatland and forest environments,
- risk removal (moving from our pesticide disposal PestSmart and, award winning, Weedwiper schemes into new areas such a nutrient removal),
- and collaborations on multi-partner projects (such as Welsh Water's SMNR catchments and NRW's Southwest 4 Rivers LIFE project).

Collaboration with new third parties:

We have good engagement with Natural Resources Wales on the management of the Crown Forestry estates within our catchment. However, we recognise that we should expand this to private forestry managers. Confederation of Forest Industries UK (CONFOR) sit on our BBMC Steering Group so we will use this contact as a way of starting these discussions.

Following learnings from our PestSmart and Beacons Water Group initiatives, we have identified a need to join-up WaterSource messages across the food supply chain. We have excellent collaborations with small-scale farmers/farming groups, but we need to better link with initiatives run by processer and distributors to ensure that safeguarding water raw water quality is part of their business assurance schemes (i.e. FAWL, Red Tractor, Crop Assurance).

Safeguard Zones:

Our measure of progress in improving catchments aligns with the Safeguard Zone designation. This designation is put in place by the NRW and is based on the quality of water in the catchment. We currently have 23 such zones and have plans in AMP7 to improve quality to allow the designation to be removed in 5 zones. Our plans in AMP8 will reduce this number by a further 5 and will move us along the path of our long-term aspirations outlined in our WSH01 Long Term Delivery Strategy.

In AMP8 investment enhancing existing or adding new controls in our catchments, will address the underlying risk of raw water deterioration and reduce customer contacts about taste, odour and colour of drinking water by 0.05 in AMP8 and mitigate risks to our CRI performance in AMP9 and beyond.

For further detail on how these schemes meet the Ofwat criteria for enhanced expenditure, see WSH53-CW01 - Improving Raw Water Quality in Drinking Water Catchments through Green Solutions.

3.2 Meeting challenges in treatment

The raw water taken from the sources described in the previous section is treated in our 62 water treatment works. Our primary aim is to ensure that we treat water to the highest standards possible and we will achieve this through maintaining the **measures already in place** and by enhance those processes where needed.

The challenges and our proposed solutions at our treatment works that cascade from the Catchments are outlined below.

3.2.1 Challenges in Treatment of Raw Water

3.2.1.1 Water quality compliance standards existing and new legislation

The level of treatment required at our treatment works vary with the challenges posed by the water quality in the catchments. As the quality of our raw waters and legislative standards change over time, our processes may become ineffective at meeting the required standard expected at our customers taps. This

results in the need to both operate our existing processes as effectively as we can and to upgrade them when necessary.

Legislative changes

The updated Drinking Water Directive, a key EU regulation, focuses on ensuring access to and the quality of water for human consumption to safeguard public health. This directive took effect in the EU in January 2021, requiring member states to incorporate its provisions into national law and adhere to them by January 12, 2023. The directive introduces new quality parameters and requirements on, for example, new and emerging risks such as PFAS. So, our consideration involves adapting to potential changes if the directive, or aspects of it, are adopted (see *Chief Inspector of Drinking Water's letter to ministers 18 July 2023*).

In the post-Brexit landscape, the devolved parliaments in the UK are pursuing varying approaches. England currently has no plans to adopt any elements of the Drinking Water Directive. Conversely, Scotland has chosen to incorporate all aspects of this directive into its legislation.

In Wales, the primary focus lies in transposing the water quality standards from the Drinking Water Directive. This is driven by the objective of maintaining existing standards within Wales and ensuring continued trade with the EU. There are ongoing discussions about the potential impact on food trade if water fails to meet EU standards. We have actively supported the Welsh Government in assessing the implications of transposing the Drinking Water Directive into the Wales Water Quality Regulations. Through this collaboration, we have determined that there is no immediate need for AMP8 investment in anticipation of these water quality standards being incorporated.

3.2.1.2 Natural Organic Material (NOM)

Solids Loading at our Treatment Works

Solids removal stages at our treatment works have envelopes of raw water quality within which they are effective. When the quality of water deteriorates beyond this envelope, the quality of the final water can decline. While we still operate the existing sites as effectively as possible, a point is reached when enhancement of those processes is required.

Disinfection by Product Formation

As nature and amount of organic material changes over time the level of disinfection byproducts will also change. The byproducts are the result of interaction between our disinfection chemicals (chlorine) and organic precursors. These precursors need to be removed by upstream processes such as coagulation but if these processes are not present or are not effective, alternatives solutions need to be found.

Pathogen Loading

Alongside introducing these physical and chemical challenges, climate change can also lead to increased microbial challenges into our source waters. These can come from agricultural runoff and are of particular challenge in our river abstractions, where we do not benefit from the attenuation of high levels of pathogens usually provided by a large reservoir.

3.2.1.3 Increased Algal activity

The increased presence of algae in our reservoirs and rivers over recent years has led to an increase in levels of compounds that lead to earthy/ musty tastes for our customers. We have seen 2-methyl isoborneol (MIB) and Geosmin in areas we have not seen it historically and more frequently in those areas where we have. The impact of climate change is leading to this phenomenon, and it is likely to increase further in the future. Warmer temperatures, more sunlight and increased nutrient runoff from the environment are all risk factors.

3.2.1.4 Manganese (our Geology and low reservoir levels) and Acceptability of Water

Along with Scottish Water, we have among the highest levels of manganese within our raw waters in the UK. In the early AMP periods (AMPs 1 and 2) treatment processes, to remove this manganese, were installed at many of our Water Treatment Works, to ensure compliance with the 50ug/L PVC standard for final water. While these processes have been largely effective in meeting this target, two things are changing.

- Firstly, some of the sites which were able to meet this standard without dedicated manganese removal stages, are now at risk of or have breached the 50ug/l standard. Cefn Dryscoed WTW is of greatest concern and
- secondly, we now know that the 50ug/L standard is not sufficient to allow us to meet our Acceptability of Water goals. As we have come to understand the causes of discolouration in our distribution systems better, we are now aware of the role that manganese plays.

In analysing our performance internally but also against others, we can see that increased levels of manganese directly correlate with the number of contacts downstream. The mechanism for this is small particles of manganese embedding themselves in the layers of biofilm that build up on the insides of our water mains. This converts the layers from being translucent to having a dark brown colour.

When flows vary, beyond their normal operating levels, these layers become detached and give the water a brown tint that is noticeable to our customers, leading them to contact us. This issue needs to be tackled in two ways, firstly reduce the amount of manganese entering our distribution system and secondly manage the build-up and detachment of these biofilm layers.

3.2.2 Options to overcome treatment challenges

To meet the challenges in the treatment of raw water, Welsh Water has followed a robust optioneering approach as outlined in WSH50-IP00 Our Approach to Investment Planning (Section 4). This section highlights the results of our shortlisting, showing where we can optimise from base-funded activities and where we need enhanced investment.

Some risks that are not adequately neutralised through solutions in the previous section on catchment interventions can be further addressed at the treatment stage.

3.2.2.1 Maintaining the effective risk controls already in place

Maintaining our existing treatment operations in good working order, to support the current levels of service from our water treatment assets, ensures that risks already under control, remain in control. We are investing base capex to maintain our existing treatment levels. This includes replacing components in our treatment works, in our labs, and in our telemetry and control systems that have reached the end of their useful life.

Some areas of focus within that Base CAPEX allowance, in response to our challenges, are detailed below.

Natural Organic Material - management and removal

We have trialled several coagulation control systems over this period and will roll out the successful ones to other sites where they can either provide an efficiency, in having an ‘always optimised’ dose of coagulant or ensure that a change raw water quality can be followed by a change in chemical dose. This, alongside the cleaning and maintenance of our solids removal stages, will keep our clarification processes running effectively.

Disinfection byproduct Mitigation

Most of our sites run at low levels of disinfection byproduct. However, we have a few treatment works where our target of 50ug/l can be more difficult to achieve. To make sure the required standards are met, we keep a close eye on current performance and respond accordingly. We do this through the use of dashboards that are circulated to operational colleagues on a daily basis throughout our “at risk” summer season. The dashboard shows the sites with the highest levels of DPBs from recent sample results, at treatment works, service reservoir and water quality zone level.

Actions undertaken would include adjustment of chemical dosing at treatment works or a decrease water age in the distribution system.

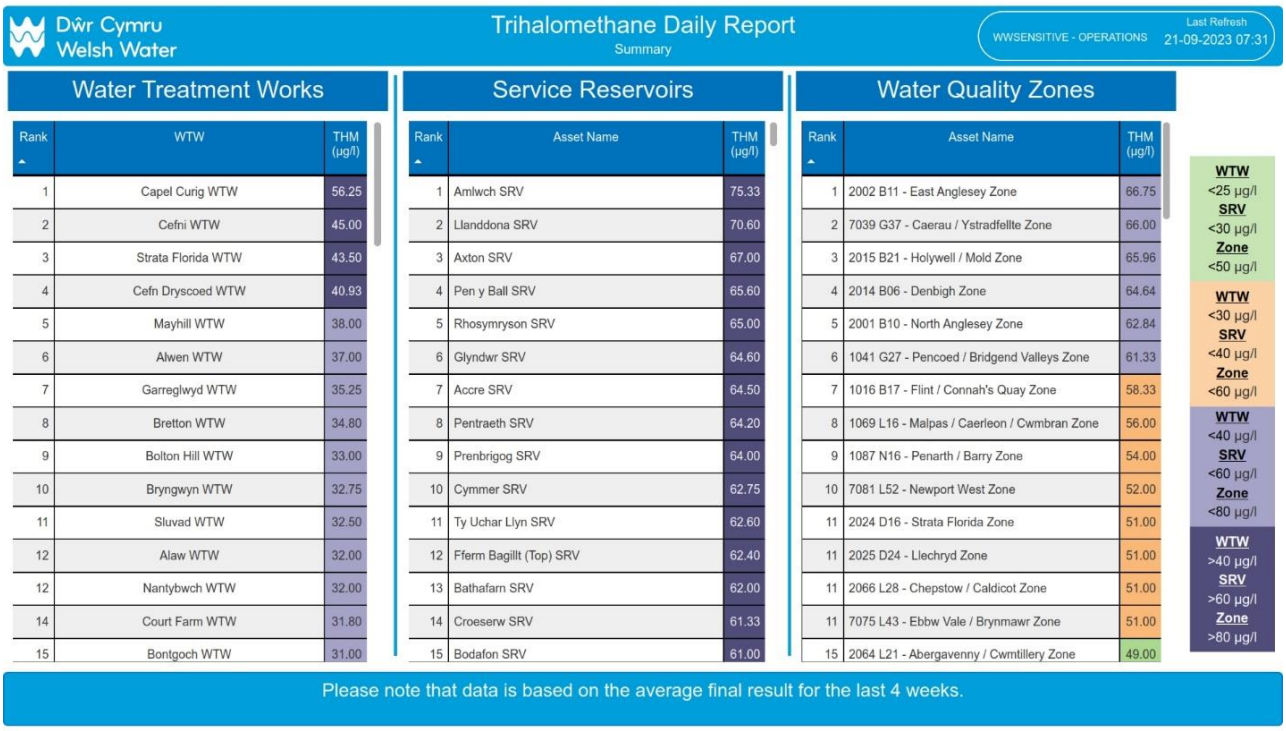

Figure 10: Our DBP dashboard

Disinfection Effectiveness and our Tank Maintenance Programme

Over the last two years we have spent a considerable amount of effort in enhancing the way we maintain the tanks in which we disinfect and store our treated water. This review was in response a dip in bacteriological compliance performance during 2021. In response, we have moved responsibility for the delivery of our tank maintenance programme under a dedicated team in our Capital Delivery Directorate. This has given the focus and engineering expertise that is needed to maintain the high standards required in this activity. We have also upgraded and digitised our inspection procedures, giving us an asset condition database, available for audit, interrogation and long-term planning. This database can be viewed in a dashboard as shown below. It shows an overall compliance with our inspection programme the numbers undertaken by operational area, and those assets that are overdue an inspection.

We have assessed our disinfection processes against the challenge posed by the raw water sources and have identified where there are shortfalls against our updated Regulation 26 Disinfection Strategy. The sites requiring upgrade are outlines in our enhancement investment case.

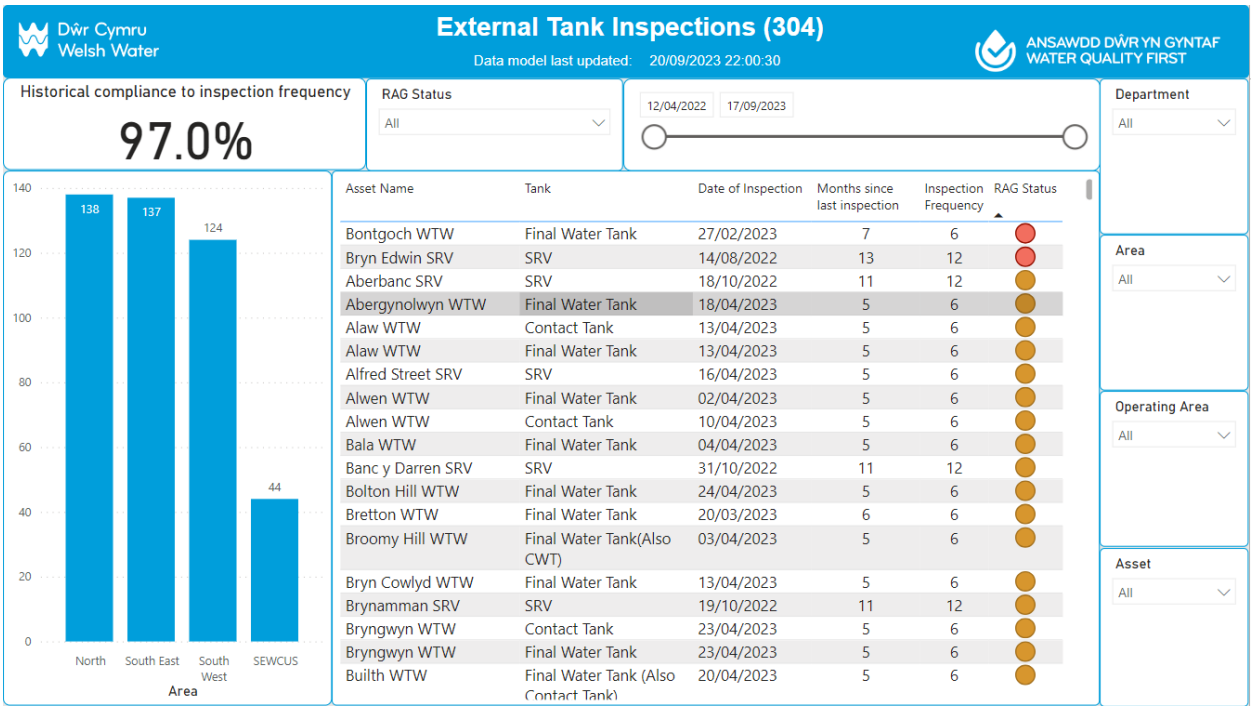

Figure 11: Our tank inspection dashboard

The Taste and Odour Challenge

Many of our sites have permanent Granular Activated Carbon (GAC) filters to remove organic pollutants such as pesticides. These filters can also remove Taste and Odour forming compounds. Where we do not have GAC, Powdered Activated Carbon (PAC) can be used in its place. As it is typically only needed for a few weeks in a year, this is an appropriate management tool for intermittent use. Some of these sites have permanent fixtures but, due to recent challenges at sites where the problem only occasionally arises, we have invested in portable treatment units that can be deployed at short notice. We use our risk-based sampling programme to identify where Taste and Odour problems may be “brewing” and communicate through another daily report and dashboard. This would trigger and record action such as switching PAC dosing on or off or adjusting the dose in response to changing levels of MIB and Geosmin in the raw/ final water.

Furthermore, when we dose water with chlorine at our treatment works, for the purposes of disinfection, we have been looking at the relationship between the temperature of the water and the amount of time for which chlorine in drinking water remains effective. In line with good practice first implemented in other water companies, we have been optimising the level of chlorine dosing at different temperatures (winter and summer) – too little chlorine would lead to compliance failures and therefore a negative impact on our CRI performance; too much chlorine typically leads to customer complaints about the taste and odour of our water.

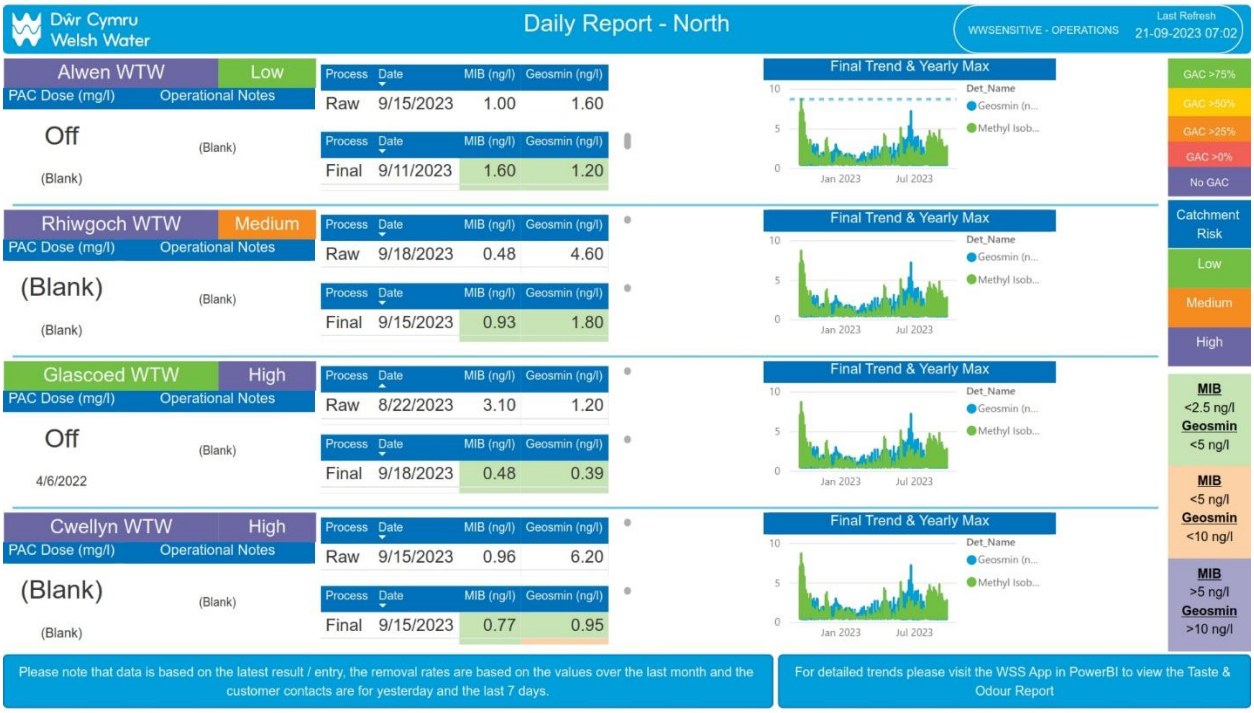

Figure 12: Our T&O dashboard

Optimising for manganese removal

Where dedicated manganese removal stages exist, optimising for manganese removal is more straightforward. The conditions can be set correctly, and the process maintained accordingly. This has become more important with our target to reduce manganese in our final waters to 1 ug/L which can be achieved on many of our sites.

However, on our sites where we do not have a dedicated removal stage, things become more complicated. There we have to trade off against treatment of other parameters, namely disinfection and residual coagulant removal. For disinfection we need to maintain the pH at a low level, while manganese removal is only effective at a higher pH. This is also the case where we need to remove the residual of aluminium based coagulants on our filters.

We monitor the performance of all our sites and now have a team dedicated to performance in this area. Our enhancement case, highlighted in subsequent section, looks to improve performance at the sites where optimisation has reached its limits. Talybont can be seen topping the dashboard below and this highlighted an issue with maintenance of the Dissolved Air Flotation lanes. The tanks needed cleaning, and this was quickly undertaken and performance returned to normal.

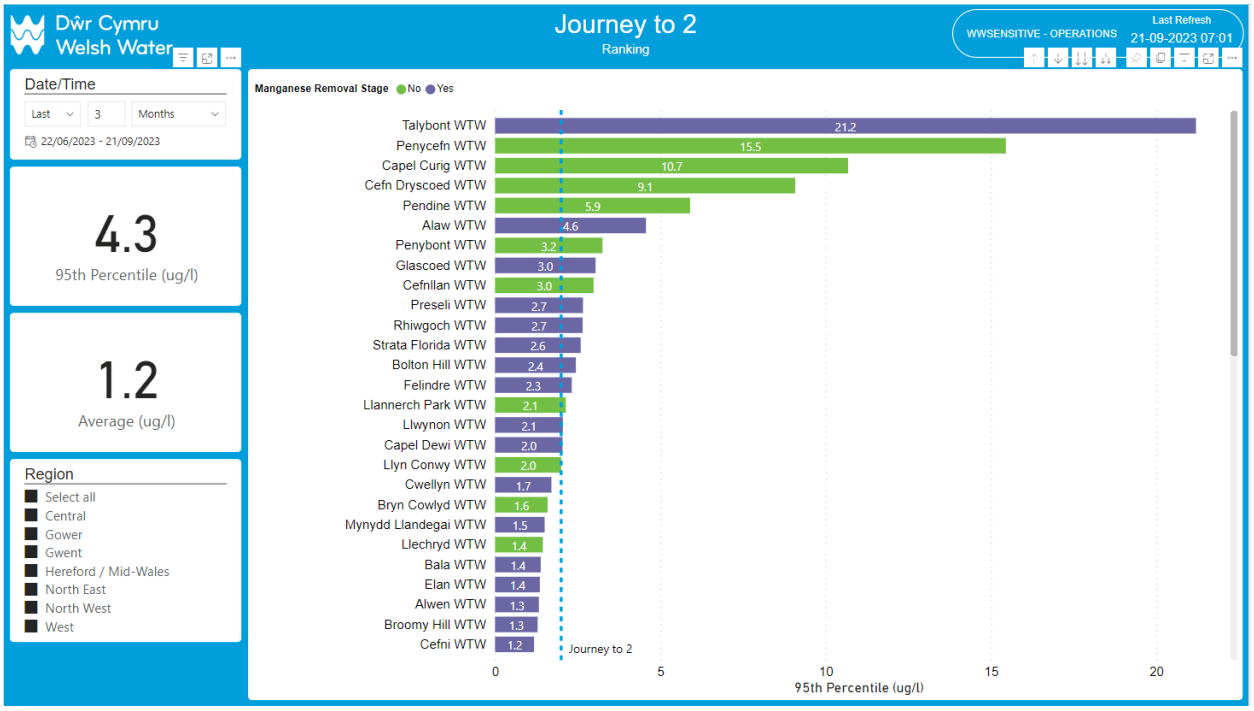

Figure 13: Our manganese dashboard

3.2.2.2 Enhancing existing or adding new resources

To address the challenges posed by the poorer quality of raw water, in addition to investing in enhanced catchment management as described above we are investing in enhanced treatment at our WTWs. The additional treatment processes include UV disinfection, dissolved organic compounds (DOC) and turbidity removal, and manganese reduction.

These schemes together will cost around £42M and reduce customer contacts by 0.08 per 1,000 customers, while also addressing long-term underlying risks to CRI. For the purposes of customer protection. The effectiveness of investment in this area is subject to governance from the DWI as described in Section 1.4.1. and performance commitments for AoW and CRI.

For further detail on how our planned interventions at WTWs meet the Ofwat criteria for enhanced expenditure, see, CW03 Improved water quality by reducing risks on water treatment works.

Enhanced DOC and disinfection by-products treatment:

Several of our treatment sites are reaching the upper end of the envelope of raw water they can maintain the high standards required. These sites and their proposed solutions are outlined in this section.

Cefn Dryscoed WTW:

The “Direct filtration” treatment process at Cefn Dryscoed WTW does not have a separate clarification stage for solids reduction or a dedicated manganese removal stage. It has one stage of filtration that must be managed to remove dissolved and solid organic material and dissolved and solid metals. While this was an appropriate and cost-effective solution when installed in the 1990s, with subsequent raw water deterioration, it has become more challenging to meet the required standards.

Our proposals for an enhanced process include the construction of a COCDAF process, which will provide a dedicated stage of treatment for organics removal, and the conversion of the existing filters to

become a dedicated manganese removal stage. This will equip the treatment works to manage further deterioration in the future and prevent a reoccurrence of an exceedance of our manganese standards in 2022. That exceedance resulted in a discoloured water event that impacted a significant number of our customers and is subject to an ongoing investigation by the DWI.

Bontgoch WTW:

Our treatment works at Bontgoch also struggles to treat the raw water under high colour conditions with these expected to increase in frequency in the future. We will upgrade the filters to ensure that they have required capacity.

Pendine WTW:

At Pendine, the deterioration of the raw water source requires a resilient solution. We will replace the existing borehole to prevent further deterioration, protecting the supply into the future.

Capel Curig WTW:

Deterioration of the level of NOM in the raw water for our Capel Curig treatment works will lead, within AMP8, to a breach of the standards for THMs (the most common form of DBPs) in the downstream supply system. The options to upgrade the existing treatment process are not deemed cost effective over the long term so the proposed solution is to abandon the treatment works and supply the distribution system from the “next door” water quality zone. This involves laying a dedicated transmission main and pumping station and will lead to a higher quality source of water for our customers.

Disinfection Byproducts on Anglesey (Alaw and Cefni WTWs):

During AMP7 we have undertaken a company-wide investigation into the levels of the disinfection byproducts called Haloacetic Acids (HAAs) to ascertain if they would meet the proposed new standards. The levels of these DBPs in most areas were satisfactory. However, on Anglesey (and at Capel Curig WTW) the levels exceeded the proposed target. We will undertake treatment trials in AMP8 to establish a solution to this issue that will form part of our AMP9 plans and line up with the expected change in legislation for this parameter.

Enhanced Disinfection treatment:

Below is a case study of our approach into enhancing our disinfection processes.

Our industry-leading Regulation 26 disinfection approach

Welsh Water has taken an industry-leading position to adapt to DWI Regulation 26

The regulation focuses on water quality with respect to protozoa and virus risks. The Regulation doesn't specify the exact method for meeting the standard; it simply requires that there be no presence of protozoa or bacteria post-disinfection that poses a public health risk. This includes levels below 1NTU. To meet this requirement, we have developed a methodology for assessing raw water quality and implemented performance criteria at each treatment stage. This comprehensive approach aligns with best practices recommended by the World Health Organization (WHO). When we presented our approach to our company DWI Inspectors, they invited us to present to all of their Inspectors to help share the best practice across other Companies.

Raw water that feeds water treatment works has been assessed to determine the level of contamination that can be presented for treatment. Credits are applied based on the existing treatment works filtration and treatment capability.

The output of this assessment has categorised the sites into three groups (high, medium, low) based on any deficits in terms of the capability to treat the raw water. This categorisation determines the timing within which remedial works are required and the extent of remedial actions (see table 7 below).

Table 7: Categorisation and timing of remedial works

Water Safety Risk Status	12-Month Log Credit	DWSP Score	DALY	Control Measure	Period for Capital Investment	Management Review Frequency
High	-3	5	$1x10^{-3}$	New control measure required	Within current AMP	Monthly DWSP
	-2.5		$1x10^{-3.5}$			
Medium	-2	4	$1x10^{-4}$	Improve source protection, Enhance treatment	By end of next AMP	
	-1.5		$1x10^{-4.5}$			
Low	-1	3	$1x10^{-5}$	Reduce uncertainty, improve operation	Within 2 AMPs	
	-0.5		$1x10^{-5.5}$			
Negligible	0	2	$1x10^{-6}$	Maintain current operation and review	N/A	Annual DWSP review
	1	1	$1x10^{-7}$			
	2		$1x10^{-8}$			
	3		$1x10^{-9}$			

The assessment has identified four sites within the medium group (a score of -1.5 to -2). These sites need to comply with the following key timeframes:

- Optimisation within 6 months

- Data validation within 12 months

- Capital investment is required in the subsequent AMP

Due to the need to comply with the enhanced requirements of Regulation 26 there is no overlap with base maintenance and a step change in performance will be required in order to maintain compliance. This works activity is fundamental to achieve the Long-Term Delivery Strategy, which focuses on avoiding any DWI failures and targeting a CRI score of 0.0. We will install UV disinfection at the four sites that has a gap of 1.5 in their log reduction requirement.

Enhanced manganese treatment:

A list of sites was reviewed to discuss historical issues, current factors that may be temporarily impacting upon performance, and future long term strategic plans for the sites to eliminate locations where intervention was needed. This provided a priority list of 11 sites where interventions, to address manganese removal, will be beneficial. The target will be to achieve 1 µg/l of manganese leaving the WTW. This list will also remain under constant review as required by our DWI notice for Acceptability of Water (DWR 2022-00004) to ensure that we continue to meet this target. With the recent improvement in the minimum detection limit at the laboratory, we will continue to review data and refine this list. The types of work planned at these 11 sites within AMP8 include enhancement of chemical mixing, enhanced filter operation and flow control, management of supernatant return, moving away from "high manganese" lime dosing and installation of cartridge filters. These interventions are being trialled in AMP7 to be rolled our more fully in AMP8.

3.3 Challenges in the distribution network

Even with a high quality of water entering the distribution system, further challenges can emerge between treatment and the customer's tap.

3.3.1 Challenges in delivery of high quality water to customers' homes

The challenges we see in the distribution system, fall into three categories

- Trunk Mains
- Distribution mains, and
- Customer Pipes

The Sections below will highlight these challenges, explain how me mitigate the issues currently and show where Enhancement expenditure will improve performance.

3.3.1.1 Trunk Mains

Oversized and Cast Iron Mains

Welsh Water has experienced a significant reduction in commercial and industrial consumption which has resulted in some mains now being over-sized. For these, it is harder to generate a 'self-cleaning' velocity, that removes internally built-up deposits. We need to invest in proactively cleaning or replacing these mains to manage the issue.

Welsh Water has identified that approximately, 40% of its water mains, which accounts for around 11,000 kilometres out of the total 27,500 kilometres, are made of cast iron or unlined ferrous material. Where trunk mains are made of this material, the corrosion products generated can have widespread impacts in the downstream system and need to be addressed at source.

Biofilm build-up and Changes in flow

Biofilm build-up within the trunk mains network can lead to water quality issues and operational challenges. While biofilm itself would naturally be translucent, it can accumulate particles of iron and manganese within its layers, ultimately becoming a potential source of discolouration. These accumulations are susceptible to mobilization with even minor changes in flow rates and need to be managed carefully.

Operational factors, such as burst mains and third-party use of our system, can cause these changes in flow rates in our mains, resulting in this mobilisation. This makes careful planning and response to burst

mains all the more crucial. Addressing these challenges involves a comprehensive approach that considers the nature of the mains and the potential for discolouration under various circumstances.

As the number of burst mains is impacted by extremes of weather resulting from climate change, we can expect these issues to become more pronounced in the future. Short-term, extreme changes in temperature in winter months leads to an increased burst rate of cast iron mains. In December 2022, for example, temperatures changed from a low of -8℃ on 16 December to +14℃ on 19 December. Such a swing was unprecedented in Wales, and resulted in supply interruptions across the operating area, along with associated discolouration.

3.3.1.2 Distribution Mains

Cast iron mains in our distribution system

Much of our cast iron mains estate is in our distribution system. Where these mains are of a smaller diameter, supplying properties in urban areas, the tuberculation that can build up on the inside of the pipe leads to restrictions in the flow of water. This becomes especially evident during high demand periods where velocities and headlosses then increase. Replacement of these mains is disruptive and expensive and is seen as a last resort. However, in the worst cases, it may be the only solution.

Changes in water quality during delivery to customers' homes

The conditions of our mains can also have an impact on the level of chlorine reaching our customers. The longer water remains in our mains, the lower the level of chlorine will fall. This is particularly true in cast iron mains, where the chlorine can readily oxidise the surface of the pipe. Temperature is also a factor in the decay of chlorine, and we see lower levels of chlorine reaching the end of our system in the summer months. This varying level of chlorine can impact the way customers perceive the taste of their water, leading to complaints. Managing these issues so all customers receive a stable level of chlorine is the challenge.

3.3.1.3 Customer Pipes – The lead pipe challenge

Lead in drinking water can pose significant health risks and result in serious health problems, particularly in children and pregnant women and immune-suppressed customers. It can affect the developing nervous system and cause learning disabilities, behavioural issues, and reduced IQ. In adults, lead exposure can result in kidney problems, high blood pressure, fertility issues, and neurological damage.

Lead pipes in the network or on customers' premises are not currently affecting our performance against CRI. However, if lead pipes are not replaced, then the risk to CRI increases over the medium to long term because:

- if the Welsh Government transposes the Drinking Water Directive into the Wales Water Quality Regulations (see Section 3.2.1.1), the limits on lead in drinking water will be tightened. It may not be possible to meet this standard through the dosing of phosphate alone.
- there is a finite supply of phosphate, used in the chemical dosing of drinking water in order to provide plumbosolvency control and minimise the risk of lead entering our water.

3.3.2 Options to overcome challenges in the delivery of water to customers

To meet the challenges in the delivery of treated water to customers' premises, Welsh Water has followed a robust optioneering approach as outlined in WSH50-IP00 Our Approach to Investment Planning. This section highlights the results of our shortlisting, showing where we can optimise from base-funded activities and where we need enhanced investment.

3.3.2.1 Effecting Change without Additional Investment

Managing how customers contact Welsh Water

Welsh Water is currently performing poorly when compared to the rest of the industry for the number of customer contacts related to discolouration and taste and odour. We will work to ensure that when customers feel the need to contact us regarding an issue with the taste or appearance of our water, information will be readily available to inform them of the causes of and resolutions to the issue.

Our contact centre is open 24 hours, 7 days per week, so that our customers can contact us with any questions, concerns or issues at a time convenient to them. We will become better at communicating messages of reassurance to our customers regarding issues they may experience in relation to the acceptability of water.

For example, communicating

- that there can be many reasons for discolouration of water - it does not necessarily mean issues in the customer's home (the potential cost of which may be a cause of concern for the customer);
- whether issues with the acceptability of water are cosmetic only or if they are an indicator that the water is unsafe;
- that discoloured water does not normally last for long and can often be cleared by running the cold water tap for a few minutes; and
- that discoloured water is fine to use to water plants, so running the cold water tap to clear discolouration need not mean wasted water.

Messages of reassurance have been available on Welsh Water's website for several years. In AMP7, we have been working to improve our offering in this space – for example, proactively pushing these messages to customers when we predict that they may experience issues (e.g., alongside alerts of mains bursts in their area). As well as continuing to provide 24-7 access to our contact centres, we will continually improve how we proactively provide our customers with relevant information regarding the quality of their drinking water. This continuous improvement in AMP8 will be funded from our base allowance and does not require enhancement investment.

3.3.2.2 Maintaining the effective risk controls already in place

Essential to securing our current level of customer contacts for water quality issues at 1.58 per 1,000 is the base spend on maintenance of the delivery network.

Trunk and Distribution Mains

Continuing control of risks as part of normal operation includes routine activities such as flushing manganese and iron deposits out of pipelines. Reaching the required flushing velocities in our trunk mains can be difficult, where this is not possible, we will develop our conditioning plans to mitigate for biofilm build up.

For the distribution system we are updating our Distribution Operating and Maintenance Strategy (DOMS). We are working with external consultants to ensure this brings best practice from the wider industry. The intention is to focus the activities on improving our iron compliance (impacting CRI), but also ensure it aligns with our plans to reduce Acceptability of Water contacts for discolouration. The plans developed from this strategy will be based on our increased coverage of hydraulic models to develop bespoke flushing plans for hotspot areas. These are called our Care Plans and will be used to maintain the improvements gained in performance over recent years and to drive down iron failures linked to deposition of corrosion products at the ends of our system. Figure 13 shows the improvements we have made where we have invested and maintained that performance with our care plans.

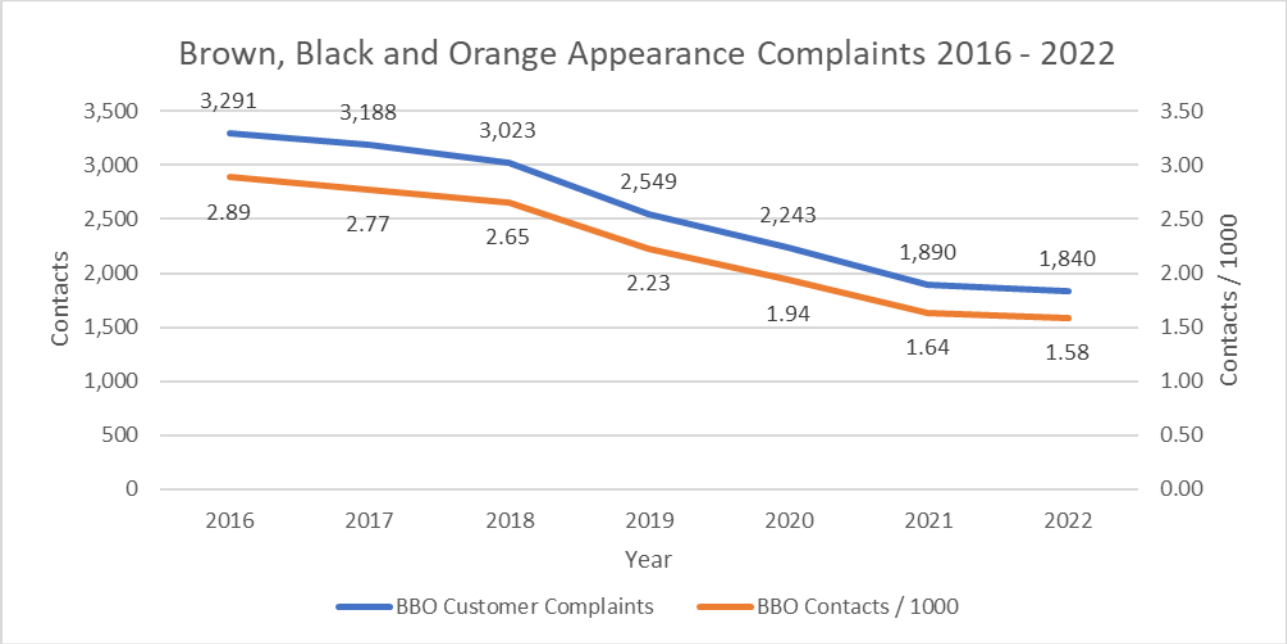

Figure 14: AOW Discolouration Customer Contacts from water quality zones which have received an intervention between 2016 and 2022

Not all our network will have the necessary ancillaries (for example hydrants and isolation valves) to undertake these activities. Enhancement funding will be required for these one-off enhancements to our system.

Consideration has been given to the option of replacing all oversized or cast iron pipes, so that they become “self-cleaning”. However, this undertaking has a very large upfront cost. To support the approach above we are scouring the global industry to find solutions but need to be cognisant of meeting all Regulatory requirements for any new processes.

To manage taste and odour complaints related to varying chlorine levels, we will continue to optimise chlorine levels at our treatment works and our boosters stations at different points in the distribution network. In AMP8 we will develop our hydraulic models to predict the level of chlorine required based on flow rates and water temperature. This will reduce the levels of variability experienced by our customers.

Lead Pipes

We will continue to dose orthophosphoric acid at the treatment works that feed our at risk zones. This dosing has been in place since the mid-1990s and has ensured our compliance with the changing lead standards. However, it is not a long term solution and removal of lead pipes is the gold standard.

3.3.2.3 Enhancing existing or adding new network assets

The two areas we need enhanced investment in our distribution system, to tackle the challenges outlined above, are improvement in Acceptability of Water contacts and in replacing lead pipes.

For customer contacts about Acceptability of Water:

The required enhancement investment for network-based interventions to improve taste, odour and colour of water has been costed at £118M and **already includes the ambitious £130M target for efficiencies set by our Board** – on top of the efficiencies already identified by the business during the

development of the business plan (see Section 1.6). The stretch target is based on our Executive team's and Board's consideration of:

- the company's historic and current performance and ability to respond to efficiency challenges in the past,
- likely opportunities from improvements to our resourcing strategy (e.g., strategic insourcing and outsourcing),
- successes from recent and upcoming procurement activities,
- and adopting innovation and good practices from other water companies.

For the purposes of improving water quality, where they can't be managed any other way, we need to replace cast iron pipes that are still structurally sound (i.e., are neither leaking nor at imminent risk of a burst) but are no longer fit for purpose and negatively impacting the quality of water they carry.

We will also be re-configuring the network to increase flexibility and automation. This strategic enhancement in AMP8 is a 'low-regret' investment. It will increase the viability and efficiency of maintenance solutions in the future (e.g., enabling more frequent network flushing and supporting automated flushing/conditioning using actuated valves) - effectively maintaining water quality while minimising disruption to customers.

The £118M enhancement investment, continuing our investment approach from AMP6 and AMP7, will result in more significant improvement to customer contacts than any other package of interventions – a reduction of 0.45 to bring our customer contacts down to 1.0 per 1,000 customers.

Additionally, our collaboration with academic institutions and the supply chain is continuing to yield valuable insights and opportunities for efficiencies. We have been trialling a magnetic device that can "treat" iron pipes to reduce the tubercules on the inside of the pipe, increasing carrying capacity and improving water quality over time. If our expanded trials are successful, this will reduce our need to implement the more expensive alternative of replacing pipes.

For further detail on how our planned network interventions meet the Ofwat criteria for enhanced expenditure, see WSH54-CW02 - Improving Acceptability of Tap Water – Networks.

3.3.2.4 The lead pipe replacement strategy

Welsh Water has drawn on its extensive experience in replacing lead supply and communication pipes to explore various options aimed at improving the efficiency and effectiveness of the plan from AMP7. These considerations include:

- **Exploring a 'lead-free zone' approach:** Initially, Welsh Water examined the strategy of replacing all lead pipes within a water quality zone, as some other water companies do. However, this approach was deemed inefficient for Welsh Water's customers in AMP8 because we cannot compel customers to replace their lead supply pipes.
- **Engaging with social housing organizations:** We have sought to benefit from economies of scale by collaborating with social housing organizations, allowing them to obtain the necessary permissions from a single property owner to replace lead pipes across multiple properties, streamlining the process.
- **Consideration of replacing communication pipes only**: We have explored the option of replacing communication pipes exclusively. While this approach offers autonomy and cost savings, it was deemed less effective because it doesn't significantly reduce the risk of lead in drinking water if the lead supply pipe remains in place.

- **Refining our prioritisation model**: To prioritise lead pipe replacement for vulnerable groups, we have used deprivation area data and demographic factors to enhance our statistical lead model. Vulnerable customers are identified based on properties likely to be fed by lead pipes, higher susceptibility to health impacts from lead consumption, and an inability to afford the full cost of lead supply pipe replacement.

- **Introducing customer Incentives**: Recognizing the high rejection rate from customers due to driveway reinstatement disruptions, we plan to introduce incentives in AMP8, including grants to partially fund lead supply pipe replacement, independent contractor selection advice, and inspections to ensure work quality.

- **Addressing driveway reinstatement costs**: For customers with expensive driveways who can afford to pay for their lead supply pipe replacement, we plan to offer to replace the pipe for free during communication pipe replacement but expect the customer to cover any additional costs for non-standard reinstatement. If the customer declines, they will be offered the alternative incentives mentioned earlier.

Continuing our "opportunistic approach": We intend to maintain the opportunistic element of our lead pipe replacement strategy. This involves economies of scale to be reaped during other activities such as leakage reduction, Project Cartref 2, or customer metering WSH56-RS00 - A Reliable Water Supply for the Short and Long Term for details on these schemes.

Based on our analysis and discussions with stakeholders, including the PR24 Forum and the Drinking Water Inspectorate (DWI), Welsh Water has determined its approach will be an enhanced investment of £14.804 million to replace 4,010 communication pipes and 3,490 supply pipes over the AMP8 period.

We believe our plan aligns with the PR24 Forum and DWI's aspirations, contributing to the Welsh Government's long-term ambition of achieving a "lead-free Wales."

- We will prioritize areas for investment based on concentrations of vulnerable customers, identified using the refined statistical lead model

- We intend to introduce customer incentives to encourage lead supply pipe replacement, addressing the issue of high rejection rates due to driveway reinstatement concerns.

- We will maintain our opportunistic approach, making the best of opportunities to replace lead pipes during other planned activities to maximize efficiency.

- Since 95% of customers received phosphate-dosed drinking water in 2022, We plan to continue dosing drinking water in AMP8 to keep the risk of lead in drinking water low.

Our plan remains flexible to adapt to future developments, such as innovative techniques, changes in public attitudes, legislative changes, or advancements in technology that may offer more efficient lead pipe replacement solutions.

For further detail on how our lead replacement plans meet the Ofwat criteria for enhanced expenditure, see WSH52-CW04 - Working towards a Lead-Free Wales.

4 Conclusion

Welsh Water is committed to making significant improvements in customer interactions, especially concerning taste, colour, and odour of water. To achieve this, we have conducted a comprehensive source-to-tap assessment of intervention options, considering all contributing factors to Acceptability of Water at each stage of the water journey.

We believe our strategy, to supply safe and high-quality drinking water to our customers' taps through AMP8 and beyond. It represents a 'low-regret' pathway in which we have balanced the need to show quick improvements to the safety and acceptability of water while addressing long-term challenges that will continue to pose risks and drive up costs if not addressed in a timely way. We have sought an optimal blend of interventions to improve parts of the source-to-tap journey of clean water that will be of the most benefit to other parts, multiplying the benefits of any single intervention. For example, interventions in a catchment that improve the quality of raw water will mean that water treatment works are under less pressure and able to work at greater capacity or need servicing less frequently.

In developing the PR24 investment plan that meets our ambitions, Welsh Water has used its TotEx solutions hierarchy to exhaust "no additional investment" or "improvement from base" options before selecting "enhancement" options (see WSH50-IP00 Our Approach to Investment Planning).

Our assessment has led us to identify a longlist of solution options that includes but is not limited to:

- managing our catchments
- enhancing existing or adding new treatment processes at prioritised works
- cleaning, flushing and replacing parts of our distribution network
- abandoning unused pipeline sections
- magnetically "repairing" rust on the inside of unlined cast iron mains
- improving communications to better meet our customers' requirement for information

To ensure sound option selection and decision-making, we have assessed all viable options based on our value framework. This comprehensive framework helps us to quantify costs, risks and benefits - including societal and environmental benefits such as long-term carbon considerations.

To ensure the robustness of our costs, we have rigorously challenged them by comparing them to the outturn costs of historical projects, using our well-established unit cost database. These costs have undergone internal and external assurance processes to ensure accuracy and reliability.

As well as looking backwards, we have looked forwards (at the latest good practice from across the industry that could be adopted at Welsh Water in AMP8; at the expected results from our collaboration with academic institutions and the supply chain to develop and implement innovative solutions) to challenge cost estimates with stretch targets for AMP8 efficiencies.

Therefore, we are confident that our plans for delivering safe and high-quality drinking water in AMP8 are the most effective, efficient and best-value mix of investments for our customers and in line with the expectations of Welsh Government, our regulators and wider stakeholders.

5 Price Control Deliverables

For cases where the delivery of benefits is not directly linked or costs cannot be fully covered by performance commitments and Outcome Delivery Incentives (ODIs), Welsh Water has clearly outlined PCDs. These specify the key outcomes or outputs expected from the enhancement expenditure, ensuring transparency for stakeholders and customers. If these outcomes are not delivered as intended, the PCDs will allow for the return of funding to our customers. The PCDs relevant to water quality are summarised below and fuller accounts are available in the two documents in the bullets below.

- WSH53-CW01 - Improving Raw Water Quality in Drinking Water Catchments through Green Solutions
- WSH52-CW04 - Working towards a Lead-Free Wales

5.1 PCD 4: Reduction in number of safeguard zones

Under the Water Framework Directive (2000/60/EC) Article 7 – Drinking Water Protected Areas (DrWPAs), where raw water quality is deteriorating, Safeguard Zones can be introduced with the purpose of recovering water quality.

Within Welsh Water's operational geography, there are currently 23 safeguard zones. Once a catchment is designated as a safeguard zone, regulators, water companies and other stakeholders are expected to work collaboratively to identify and implement targeted measures with the aim of addressing the root cause of any pollutants.

A number of measures are used to assess the need for a safeguard zones. These are outlined in the table below along with the criteria that are required to demonstrate improvement from the necessary safeguard zone action plans:

Table 8 - Assessment criteria for safeguard zones

Risk Assessment	Evidence Criteria
DWI Undertakings or reportable events	No further Undertakings or reportable events
Drinking Water Safety Plan scores	Annual completion of DWSPs and submission to DWI
Known land use changes/catchment activities	Influence Land Use Changes and Land Management practices Influence Stakeholder Activities Number of different stakeholders engaged and/or participating in WaterSource schemes Active communication methods adopted Identify and/or Stop Source Pathways Reduce Pesticide and / or Nutrient losses Reduce Polfaxes / WIRs
Spatial risk mapping identified 'hot-spot' areas of concern with known source-to-receptor pathways	
Raw water parameter, exceedance of PCV	
Raw water detection of 'hard to treat' substance e.g. metaldehyde, propyzamide, carbetamide, clopyralid, quinmerac and metazachlor	

Risk Assessment	Evidence Criteria
Strong raw water deterioration from baseline assessment	Improve Water Resource Management Improving water quality at field scale and/or abstraction point
Increase in final water exceedances of PCV	Improve WTW Performance Reduce customer contacts Reduce Chemical and/or Energy Use No source abandonment
Increasing operational costs, additional blending or need for capital investment	
Risk of source abandonment	

In line with ongoing works in AMP7, Welsh Water is looking to influence stakeholders to improve the underlying water quality in a number of catchments. We will continue to target actions in 5 catchments with safeguard zone status by the end of AMP7.

As projected in PR19, Welsh Water's long-term ambition is to reduce the number of catchments with safeguard zone status to 5 by 2050. Due to the size and complex root causes, often outside of our control, which can result in catchments being classified as safeguard zones, it will become increasingly difficult to achieve this target. Also, as our actions can be on third party land and the Regulator decides the designation, the removal of a classification is outside of our management control.

Where the improvements required to remove a catchment from safeguard zone status are beyond our influence, it is beneficial to have status remain in place as it gives the regulator (NRW) more leverage to influence third parties to make improvements.

5.2 PCD 7: Lead pipe replacement

We have been undertaking a lead pipe replacement programme in AMP7. As part of PR24 planning, our Board has re-confirmed its commitment to achieving the strategic aspiration of working towards a lead-free Wales.

Our current performance is behind our initial AMP7 plan due to the restrictions in place during the pandemic. We now have plans in place to recover this position to hit our end of AMP7 target of replacing 7,000 pipes.

Our AMP8 plan includes a total investment of £14.804 million to address lead risk for customers, replacing 4,010 communication pipes and 3,490 supply pipes over the AMP8 period, including 2,200 from the provision of a customer grant.

Welsh Water's long-term ambition is to achieve the Welsh Government target of a "lead-free Wales". This will require the replacement of circa 150,000 of each lead communication and supply pipes. As described in the WSH01 Long Term Delivery Strategy document, Welsh Water's milestone for 2050 is to replace 100,000 lead pipes across AMPs 8 to 12. In light of these ambitions, the DWI has suggested that we consider increasing our AMP8 investment to help smooth the profile of lead pipe replacement over the next 25 years. After careful consideration of this challenge, we believe that 7,500 lead pipes is the most appropriate size for the AMP8 programme.