PR24

NORTHUMBRIAN WATER living water | ESSEX&SUFFOLK WATER living water

A3-08 ENHANCEMENT CASE WN - RAW WATER DETERIORATION (GEOSMIN)

NES21

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1. INTRODUCTION

To make sure that our customers consistently receive drinking water that is clean, clear, and tastes good, it is vital that we continue to identify, understand, and appropriately manage risks to our water supply systems so they remain resilient today and over the long term. The Water Services Regulation Authority (Ofwat) defines resilience as 'the ability to cope with, and recover from, disruption and anticipate trends and variability to maintain services for people and protect the natural environment now and in the future'[1]. For PR24, we have focused on the resilience of our water supply systems in terms of managing raw water quality. Therefore, we have put a focus on identifying and understanding raw water quality trends to make sure we can cope with existing water quality challenges and those we anticipate in the future to maintain our services.

Our best practice prioritises proactive management of drinking water quality across the entire water supply system. This includes managing water quality parameters below our internally set prescribed concentration or value (PCV) levels from catchment sample points through to the customer's tap. We have intentionally set our internal PCV levels lower than the drinking water threshold set for customer's taps by the Drinking Water Inspectorate (DWI), and at a point at which experience tells us we will have enough time to respond and correct any issues before water reaches our customers.

Our best practice includes catchment management processes that are designed to monitor and safeguard the catchment environment to reduce the movement of nutrients, organics, and other potential water quality contaminants to make sure we collect clean water into our sources. As we do not own all land within our catchments, we are reliant on responsible land management practices by private landowners. Therefore, stakeholder engagement remains a focus for our catchment teams to educate and encourage responsible land management practices.

Through our recent vulnerability assessment of our water treatment processes to changes in raw water quality, we identified that our customers in our Northumbrian region who receive drinking water from Broken Scar and Warkworth water treatment works (WTWs) could experience taste and odour (T&O) impacts by the end of the 2025-30 period. This is due to rising levels of Geosmin in raw water and the inability of these WTWs to reduce levels. Geosmin is naturally occurring, but high levels in drinking water can be responsible for unacceptable T&O in tap water.

In September 2020, South West Water was fined over £240,000 due to an offence under s.70 of the Water Industry Act 1991 for the supply of water unfit for human consumption[2]. This was due to prolonged high levels of Geosmin in their tap water and their lack of an appropriate response to rectify this. We are also mindful that during the 2020-25 period, we are investing in extra treatment capability at our Ormesby WTW for Geosmin removal in response to a T&O event in July 2021. With these instances in mind, we completed a vulnerability assessment and developed this business case for Geosmin as a proactive means of ensuring our resilience with maintaining the quality and acceptability of our drinking water. Therefore, we have identified a need for AMP8 investment at our Broken Scar and Warkworth WTWs to improve our resilience with

[1] Resilience in the round, Ofwat, 2023
[2] Press release: Southwest Water fined for drinking water offence, DWI, 2020

managing Geosmin in our raw water to make sure our customers consistently receive drinking water that is clean, clear, and tastes good. In August 2023, we received letters of support from the DWI to address our Geosmin needs at Broken Scar and Warkworth WTWs. We propose to do this through implementing Geosmin-removal capability at the WTWs through powdered activated carbon (PAC). The enhancement investment required to do this in the 2025-30 period is **£8.048m**, as summarised in Table 1.

TABLE 1: ENHANCEMENT INVESTMENT REQUIRED TO ADDRESS OUR GEOSMIN NEED IN AMP8

Site	Total AMP8 Capex	Opex (annual)	AMP8 Totex
Broken Scar WTW	£3,682m	£0.192m	£4.259m
Warkworth WTW	£3,177m	£0.204m	£3.789m
TOTAL	£6.860m	£0.397m	£8.048m

2. NEED FOR ENHANCEMENT INVESTMENT

2.1. ALIGNMENT WITH STATUTORY PLANNING FRAMEWORKS

As a water company, we are obligated to supply drinking water to our customers that is considered 'wholesome'. This is defined within the Water Supply (Water Quality) Regulations 2016, as a series of strict water quality standards that must be consistently met[3]. These standards have been set to protect public health as well as considering qualities of water that make it acceptable to customers, such as the way it looks, smells, and tastes. Therefore, the standards cover micro-organisms, chemicals, metals, and aesthetic parameters such as taste and odour.

2.2. VULNERABILITY ASSESSMENT

To make sure we continue to consistently provide drinking water to our customers that is clean, clear, and tastes good, during 2022 we completed an assessment of the vulnerability of our water treatment processes to changes in raw water quality. Our assessment reviewed all available raw water data for sources that supply water to our 53 WTWs and identified rising levels of Geosmin in raw water across our regions. Our assessment then considered the capability of our existing treatment processes at these sites to manage high Geosmin levels and identified where we have treatment limitations and are therefore most vulnerable. We used the outcomes of our vulnerability assessment to inform our priority sites for Geosmin for investment in the 2025-30 period. Below we provide more detail on our assessment of Geosmin in our raw water.

2.2.1 Analysis of raw water sample data

We began routinely monitoring for the T&O compounds Geosmin and 2-methylisoborneol (MIB) in 2016 when our laboratories introduced this capability. The DWI has not set a drinking water threshold for Geosmin; however, we have set an internal PCV level for Geosmin to enable us to effectively manage this contaminant, and we monitor Geosmin level in both raw and final water.

During our 2022 vulnerability assessment, we analysed all our Geosmin and MIB data to understand trends that may be present. For each raw water point, we determined the 95th percentile for each year and established a linear trend of this data to forecast a rate of change across the next two AMP periods.

2.2.2 Establishing a risk trigger level for raw water

To inform our analysis and determine the point at which any Geosmin levels are likely to impact our customers, we defined a 95th percentile raw water trigger level of 9 ng/L as the point at which treated water is likely to contain sufficient Geosmin to result in customer T&O complaints. While the 9 ng/L trigger level for raw water is not a regulatory one, it is based on the following rationale that considers the latest literature on customers' sensitivity to Geosmin and water treatment removal capabilities:

[3] The Water Supply (Water Quality) Regulations 2016

- UK Water Industry Research (UKWIR) and Water Research Council research has demonstrated that Geosmin can be detected in water taste tests at a minimum concentration of 1.25 ng/L by some customers, but the median level of detection is 3.75 ng/L. Customers most frequently described such levels as having a 'musty', 'mouldy', or 'earthy' taste. While there are no expected risks to human health from such levels, the UKWIR Toxicity database[4] records a Suggested No Adverse Response Level (SNARL) for Geosmin in treated water of 1-4 ng/L to ensure effective management of T&O impacts.
- In 2014, the DWI published a paper outlining the risks associated with compounds that contribute to T&O in water supplies[5]. The paper examined many T&O compounds, both anthropogenic and naturally occurring, assessing removal rates across different treatment stages. Coagulation and filtration do not provide any removal of Geosmin, and therefore control of T&O impact is reliant on disinfection and PAC dosing. While a dedicated PAC unit can remove approximately 85% of Geosmin from raw water, the disinfection process is limited to approximately 46% removal. Therefore, our WTWs with no existing PAC capacity will be limited to 46% removal across the process.

Our risk-based raw water threshold of 9 ng/L (95th percentile) is derived from the above research by applying the simple principle that where our WTWs are largely reliant on disinfection for Geosmin removal, raw water levels consistently more than 9 ng/L are likely to result in levels greater than the UKWIR SNARL of 4 ng/L in the water supply, which are proven to be sufficient to impact our customers, resulting in T&O complaints. We therefore used the raw water trigger of 9 ng/L in our vulnerability assessment, to identify which sites are expected to exceed this by the end of the 2025-30 period.

[4] Toxicology Datasheets, UKWIR, 2021
[5] National assessment of the risks to water supplies posed by low taste and odour threshold compounds, DWI, 2014

2.2.3 Vulnerability assessment outcomes

Through our vulnerability assessment, we identified 21 raw water sample points where Geosmin is already exceeding or is projected to exceed our trigger of 9 ng/L in the raw water by the end of the 2025-30 period. These raw water sample points are listed in alphabetical order in Table 2, alongside the WTW they supply water to, and the capacity of that WTW to remove Geosmin. Of the 21 raw water sample points identified, two do not have capacity within the existing processes to effectively remove Geosmin to mitigate the risk: Broken Scar and Warkworth WTWs (Table 2). At Broken Scar, there are granular activated carbon (GAC) units on site which were installed in 2003 for the removal of organics. However, they have insufficient Empty Bed Contact Time required to effectively reduce levels of Geosmin in raw water. At Warkworth WTW, we have both GAC and PAC on site; GAC was installed in 2007 specifically for the removal of pesticides from raw water. Despite this, both WTWs have insufficient capacity to effectively reduce levels of Geosmin in raw water.

Therefore, to make sure we continue to meet our statutory obligations for providing wholesome drinking water to our customers as outlined in the Water Industry Act 1991, we need to be able to mitigate the impacts of elevated Geosmin levels in raw water at Broken Scar WTW and Warkworth WTW. These are our priority sites for Geosmin in AMP8. Our Geosmin trends are explored in more detail in the sections that follow.

TABLE 2: OUTCOMES OF OUR VULNERABILITY ASSESSMENT FOR GEOSMIN, SHOWING RAW WATER SAMPLE POINTS WHERE PROJECTIONS EXCEED 9 NG/L BY THE END OF THE 2025-30 PERIOD[6]

	Raw water sample point	Associated WTW	Raw water data trend	Existing Geosmin treatment capacity	Treatment description	Additional mitigation measures required in AMP8?
1	BROKEN SCAR RAW - RIVER TEES	Broken Scar	Deteriorating	No	GAC process units on site but insufficient Empty Bed Contact Time for adequate mitigation.	Yes
2	CATCLEUGH RESERVOIR	Gunnerton, Byrness, Rochester and Otterburn	Deteriorating	Yes	PAC and GAC, some evidence that membranes can remove between 5%-40%	No
3	GREAT NORTHERN RES (W DENE)(2)	Whittle Dene	Deteriorating	Yes	PAC and GAC process	Yes – Catchment mitigation through BAU or WINEP
4	GREAT SORTHERN RES (W DENE)(8)		Deteriorating	Yes		
5	LOWER RESERVOIR (W DENE)(5)		Deteriorating	Yes		
6	NORTHERN RESERVOIR (W DENE)(3)		Deteriorating	Yes		
7	WESTERN RES (W DENE)(4)		Deteriorating	Yes		
8	WHITTLE DENE RAW		Deteriorating	Yes		
9	HANNINGFIELD RAW RESERVOIR OUTLET	Hanningfield	Deteriorating	Yes	Pre and post Ozone and GAC units	Yes – Catchment mitigation through BAU or WINEP
10	HORSLEY RAW	Horsely	Deteriorating	Yes	PAC & GAC process	No
11	LANGFORD RIVER BLACKWATER	Langford	Deteriorating	Yes	Pre-Ozone and GAC units	No
12	LANGFORD RIVER CHELMER		Deteriorating	Yes		No

[6] Northumbrian Water vulnerability assessment

	Raw water sample point	Associated WTW	Raw water data trend	Existing Geosmin treatment capacity	Treatment description	Additional mitigation measures required in AMP8?
14	LARTINGTON RAW - BALDERHEAD RESERVOIR	Lartington	Deteriorating	Yes	PAC (AMP7 capital project will replace existing plant)	No
15	LARTINGTON RAW - HURY RESERVOIR		Deteriorating	Yes		No
16	LR5 ABBERTON (PATERSON WEIR)	Layer and Langford[7]	Deteriorating	Yes	Biological slow sand filtration with GAC sandwich construction	No
17	LUMLEY RAW	Lumley	Deteriorating	Yes	PAC and GAC (PAC requires refurbishment)	No
18	ORMESBY FINAL RAW	Ormesby	Deteriorating	Yes	Slow sand filtration available to River Bure abstraction	No
19	RIDING MILL PSTN (R TYNE)	None. Direct supply.	Deteriorating	Yes	PAC installed on the Broad abstraction that goes straight into supply. PAC was installed in 2021 following a water quality incident	No
20	RIVER STOUR (LOWLIFT)	Langham	Deteriorating	Yes	Biological slow sand filtration with GAC sandwich construction	No
21	WARKWORTH RAW	Warkworth	Deteriorating	No	PAC and GAC, but insufficient capacity. PAC limited to 5mg/l max dose	Yes

[7] We are currently constructing a pipeline that will transfer raw water from Abberton Reservoir to Langford WTW, as a means to improve resilience in the region.

2.3. AMP7 PROGRESS

During the 2020-25 period, we needed to invest urgently in Geosmin treatment at Ormesby WTW in our Essex & Suffolk Water region, due to an increase in Geosmin levels causing an impact on water supply. Ormesby WTW supplies 98,000 people in the Great Yarmouth area and has two distinct treatment streams: the River Bure and Ormesby Broad. While the two streams provide a degree of operational flexibility and resilience to deal with water quality challenges, we were not able to effectively maintain the aesthetic quality of water in the water supply zone in July 2021 and we received some T&O customer contacts. Though contact numbers were low, this became a notifiable event to the DWI, and subsequent investigations confirmed elevated levels of Geosmin and MIB compounds coming from Ormesby Broad.

To immediately improve resilience, we hired and installed a temporary PAC dosing system as a preventative measure to make sure we could continue to treat raw Ormesby Broad water containing Geosmin if problems occurred with the River Bure source. Initial performance of the temporary unit demonstrated 60% removal on the Broad process stream, which was a good result. The PAC dosing also proved effective in addressing the T&O contact issue. While the temporary PAC unit provided an immediate level of mitigation, capacity was insufficient to adequately address the risk beyond the short term, given that Ormesby operation is heavily reliant on the undependable Bure source which itself is at risk of high metaldehydes and turbidity.

In addition to this, there would have been significant operating costs if we continued to hire a temporary dosing unit, and so we decided to install a permanent solution within the 2020-25 period as the most efficient long-term solution. Therefore, although the investment at Ormesby was required to address a raw water deterioration risk (and so would have been enhancement), we have funded the solution from our existing revenue allowances in AMP7 to expediate the best option for customers. To ensure ongoing resilience to rising Geosmin levels, we installed a permanent PAC dosing facility with the capability to treat peak flows. The project was delivered in April 2023. Building on this experience in the 2020-25 period, our vulnerability assessment for Geosmin has allowed us to proactively implement a strategy for monitoring high-risk sites and identify two priority sites for AMP8 where raw water deterioration will require action to maintain resilience.

2.4. OUR PRIORITY SITES FOR AMP8

As mentioned in Section 2.2.3, our vulnerability assessment identified two sites as being our priority for investment in the 2025-30 period: Broken Scar and Warkworth WTWs. Our assessment highlighted that Geosmin from the River Tees source, the primary supply of raw water to Broken Scar WTW, consistently has Geosmin present which peaks seasonally (up to 13 ng/L), and in late 2020 began to exceed our trigger level of 9 ng/L. Our assessment also identified that Geosmin from our Warkworth source that supplies water to Warkworth WTW is consistently present and seasonal. These seasonal peaks have been increasing in intensity (concentration) and frequency, exceeding our trigger level of 9 ng/L since 2020 and reaching up to 25 ng/L.

TABLE 3: THE 95TH PERCENTILE GEOSMIN DATA FOR THE TWO PRIORITY SITES AND PROJECTED CONCENTRATIONS BY THE END OF AMP8[8]

Location	95 percentile for each year (ng/L)							Predicted end-AMP8 (2030) concentration (ng/L)	Historical maximum concentration (ng/L)
	2016	2017	2018	2019	2020	2021	2022		
BROKEN SCAR RAW - RIVER TEES	1.00	1.84	2.00	3.64	3.10	7.12	2.42	9.27	13
WARKWORTH RAW	6.57	8.91	6.17	4.39	7.69	9.26	20.85	26.83	24

To investigate how Geosmin at these sites may change over the 2025-30 period, we measured the 95th percentile for each year and added a linear trend to the data. In this way, we have estimated the concentration of Geosmin in the raw water that supplies both Broken Scar and Warkworth WTWs by the end of AMP8 as shown in Table 3. Historical Geosmin levels and projections to 2040 are shown in Figure 1 and Figure 2 for Broken Scar and Warkworth WTWs respectively.

We installed a PAC plant at Warkworth WTW in the early 2000's as a general mitigation measure to catchment pollution, as we have a direct river abstraction which is sensitive to changes in the environment. Despite having this treatment present, the dosage it was designed with is not suitable for Geosmin removal.

[8] Northumbrian Water assessment of sites

FIGURE 1: HISTORICAL GEOSMIN LEVELS AT THE 95TH PERCENTILE FOR EACH YEAR FROM BROKEN SCAR WTW RAW WATER POINT DEMONSTRATING AN INCREASING TREND, ALONGSIDE OUR TRIGGER LEVEL (9 NG/L)

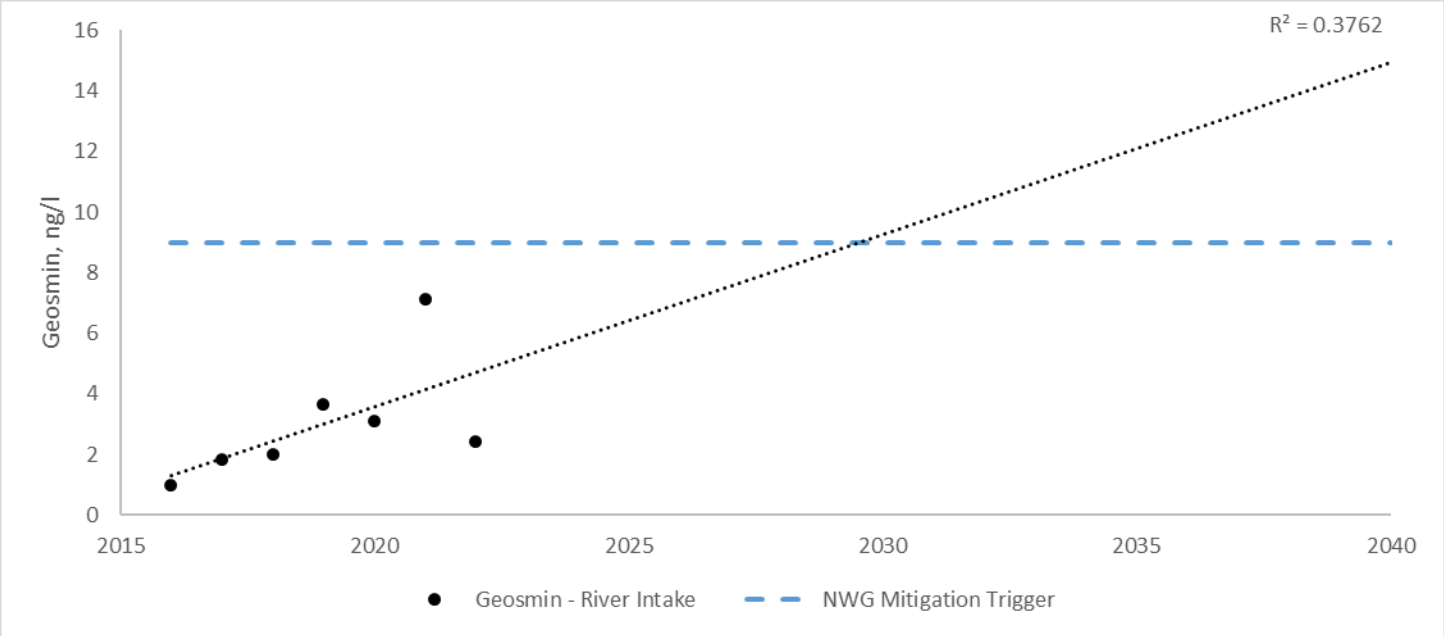
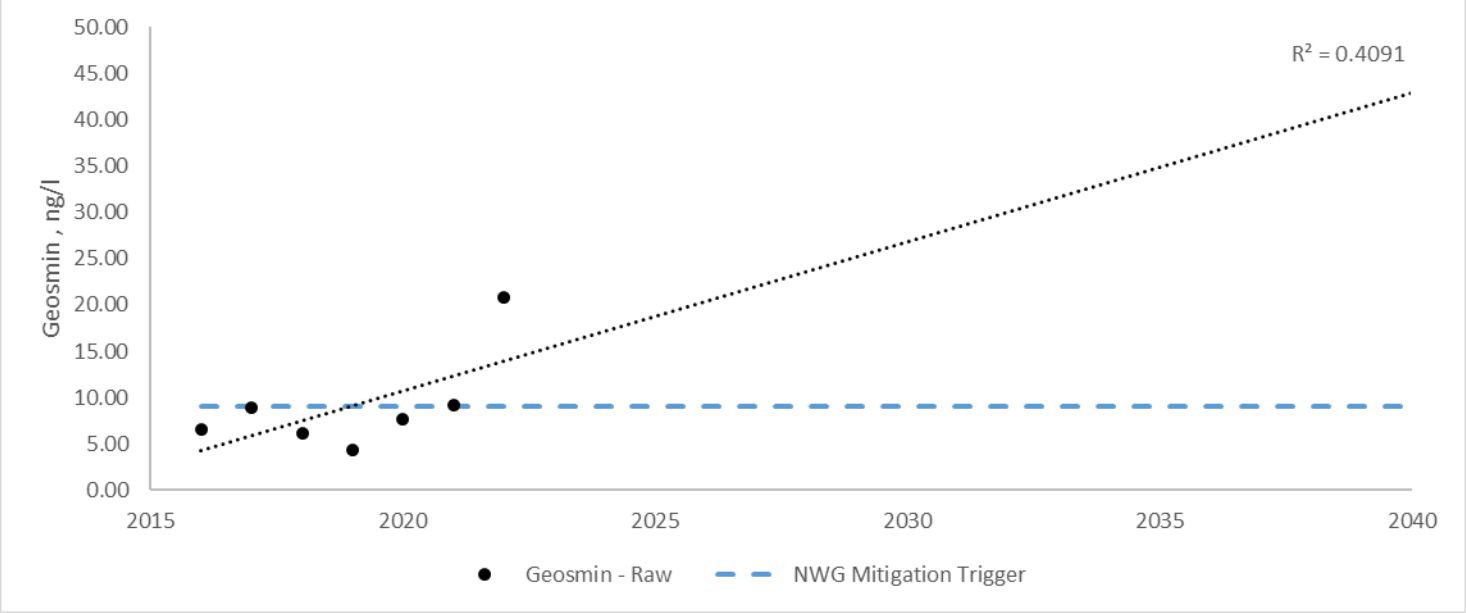


FIGURE 2: HISTORICAL GEOSMIN LEVELS SHOWN AT THE 95TH PERCENTILE FOR EACH YEAR FROM WARKWORTH WTW'S RAW WATER POINT DEMONSTRATING AN INCREASING TREND, ALONGSIDE OUR TRIGGER LEVEL (9 NG/L)



2.5. DETERIORATING WATER QUALITY IS AFFECTING OUR CUSTOMERS

The majority of our WTWs were not designed to remove Geosmin. Therefore, should there be elevated levels in our raw water, it will typically move through our treatment works towards our customers. Our routine and responsive water quality monitoring practices allow us to keep an eye on Geosmin levels and enable us to take action to avoid it moving through to our customers. However, we have established channels through which our customers can contact us about T&O (aesthetic) water quality concerns.

Since 2019, we have been collecting customer contact information including for aesthetic concerns such as 'earthy / musty' T&O which is indicative of the presence of Geosmin. This data is heavily reliant on an individual's sensitivity to Geosmin, and reliant on them reaching out to us through our established channels. Therefore, this data can help to notify us where there are aesthetic issues, but we remain reliant on our water quality monitoring for Geosmin to inform our operations earlier in the system to prevent customers being impacted.

Table 4 provides a summary of the 'earthy / musty' T&O contacts we have received that are associated with our two priority sites. It indicates that our customers are being impacted by Geosmin and/or MIB. Contacts levels have been relatively consistent for Broken Scar WTW with a total of 33 contacts over the past four years. Conversely and fortunately, there have been fewer contacts for Warkworth WTW, at only two over the past four years. This may reflect our Geosmin monitoring and operational response actions working effectively.

As outlined in Table 2, our priority sites have GAC present but not at the capacity required to effectively remove Geosmin. These processes however may be providing a degree of Geosmin removal despite not being designed to do so. The low number of customer contacts associated with water from Warkworth in Table 4 indicates that this may be the case.

TABLE 4: CUSTOMER CONTACT INFORMATION RELATED TO THE PRESENCE OF GEOSMIN AND MIB FOR THE SIX PRIORITY SITES[9]

Site	Number of Customer Contacts due to 'earthy / musty' taste and odour				
	2019	2020	2021	2022	Total
Broken Scar WTW	9	10	8	6	33
Warkworth WTW	0	0	1	1	2

[9] Northumbrian Water customer contact data

2.6. BASE EXPENDITURE FOR AMP8

2.6.1 Base vs enhancement

The assumptions we have made to allocate investment to base or enhancement to address our Geosmin needs are outlined in Table 5.

TABLE 5: OUR ASSUMPTIONS AROUND BASE AND ENHANCEMENT INVESTMENT

Base	Enhancement
• Ensuring a WTW is operating as it was designed to • Improving the efficiency of operations • Items funded at previous price reviews	• Improving service quality • Improving water supply resilience against impacts of climate change

Investment at Broken Scar WTW is enhancement only, on the basis that the site was not designed to treat Geosmin and has no existing PAC capacity. Investing in PAC at this site will improve our resilience to impacts of climate change.

Warkworth WTW, while not designed to treat elevated levels of Geosmin, does have a small existing PAC plant and we have taken its capacity into account in determining the overall capacity required to mitigate the Geosmin risk. The option for PAC treatment is calculated based on the difference between the capacity of the existing unit and that is required to provide robust Geosmin treatment.

We have not received investment funding from Ofwat in the past to address Geosmin in raw water at Broken Scar and Warkworth WTWs.

2.6.2 Link to Long Term Strategy

This investment is needed as part of the 'ensuring sustainable water supplies' investment area under our Long-Term Strategy (LTS) core pathway.

To inform our strategy, we monitor raw water parameters and forecast future requirements to assess where projected trends in raw water quality pose a risk to service. This case to invest in 2025-30 at two of our WTW sites due to rising Geosmin levels is the output of our analysis.

We have a legal obligation to provide wholesome drinking water to our customers as outlined in the Water Industry Act 1991. We consider this investment is needed in 2025-30 to make sure we continue to meet this obligation as we need to be able to mitigate the impacts of elevated Geosmin levels in raw water at Broken Scar and Warkworth WTWs. We therefore consider this investment is necessary in 2025-30 to deliver our LTS.

We will continue to monitor Geosmin levels in raw water to determine whether further investment will be required beyond 2030.

2.7. CUSTOMER SUPPORT FOR THE NEED

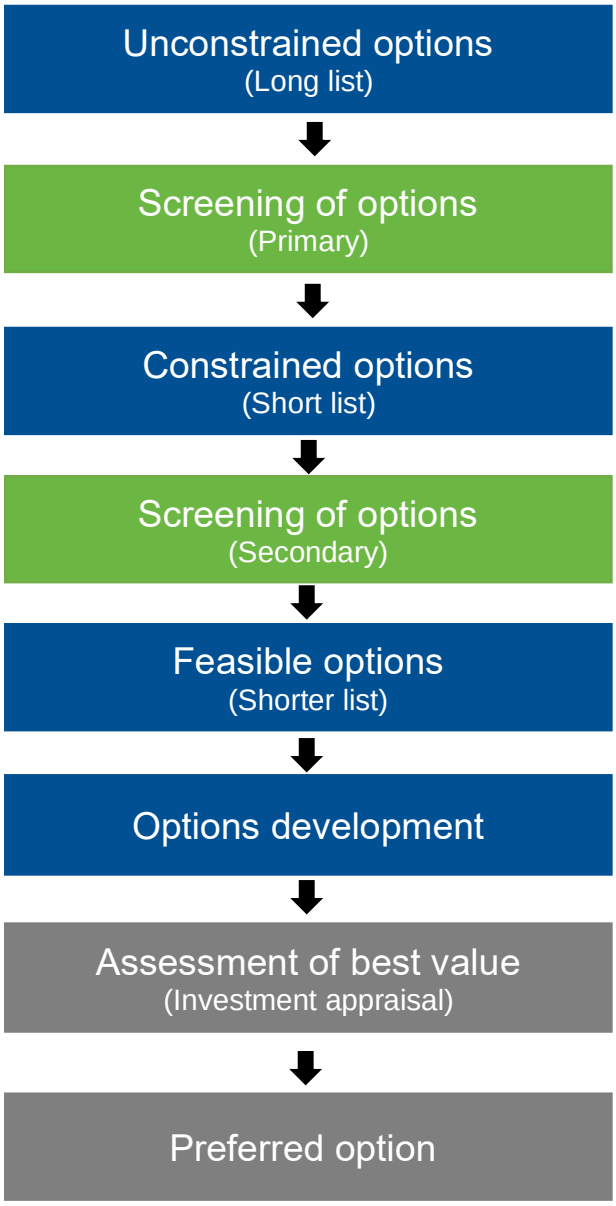
Our customers consider water quality to be a high priority (for both compliance risk index and water quality contacts, see our **prioritisation of common performance commitments,** NES44).

Our customers expect us to meet our obligations to provide wholesome drinking water, and we must make these investments to do so (see Section 2 on the statutory need for these investments).

3. BEST OPTION FOR CUSTOMERS

To determine the best option for customers to address the need, an options identification and screening process as outlined in Figure 3 was carried out. Our process for identifying the best option for customers is based on the principles of The Green Book: Central Government Guidance on Appraisal and Evaluation produced by HM Treasury[10]. A full description of each step and the output from it is contained in the following sections.

FIGURE 3: REPRESENTATION OF THE OPTIONS DEVELOPMENT AND SCREENING PROCESS TO IDENTIFY THE BEST OPTION FOR CUSTOMERS



Unconstrained list of options (Section 3.1)

We have developed a broad range of options which consider the 4Rs of resilience: Resistance, Reliability, Redundancy, and Response and Recovery.

Constrained list of options (Section 3.2)

To identify a constrained list of feasible options capable of meeting the need, we screened the unconstrained list of options against two criteria for our priority sites:

1) guaranteed Geosmin removal in AMP8 to less than 9 ng/L in raw water, and
2) technical feasibility

Options development (Section 3.2)

We have developed scope to Level 2 using our iMOD system and spread investment across AMP8. We have carried out an assessment of benefits for each option from the constrained list at each site using the Northumbrian Water Value framework and guidance set out in the PR24 Final Methodology Guidance.

Assessment of best value (Section 3.3.1)

We have used our information on costs and benefits, to carry out an assessment of net present value for each option. Our plan includes only those projects which are cost beneficial.

Preferred option (Section 3.3.2)

We have selected the preferred options based on the outcomes of the best value assessment, to maximise value for customers and environmental outcomes while achieving the regulatory requirement for each need.

[10] The Green Book: Central Government Guidance on Appraisal and Evaluation, HM Treasury, 2022

3.1. BROAD RANGE OF OPTIONS

We have developed a broad range of 18 options to address the Geosmin need as shown in Figure 4. Our options are categorised according to the 4Rs of resilience, which is linked to our vulnerability assessment:

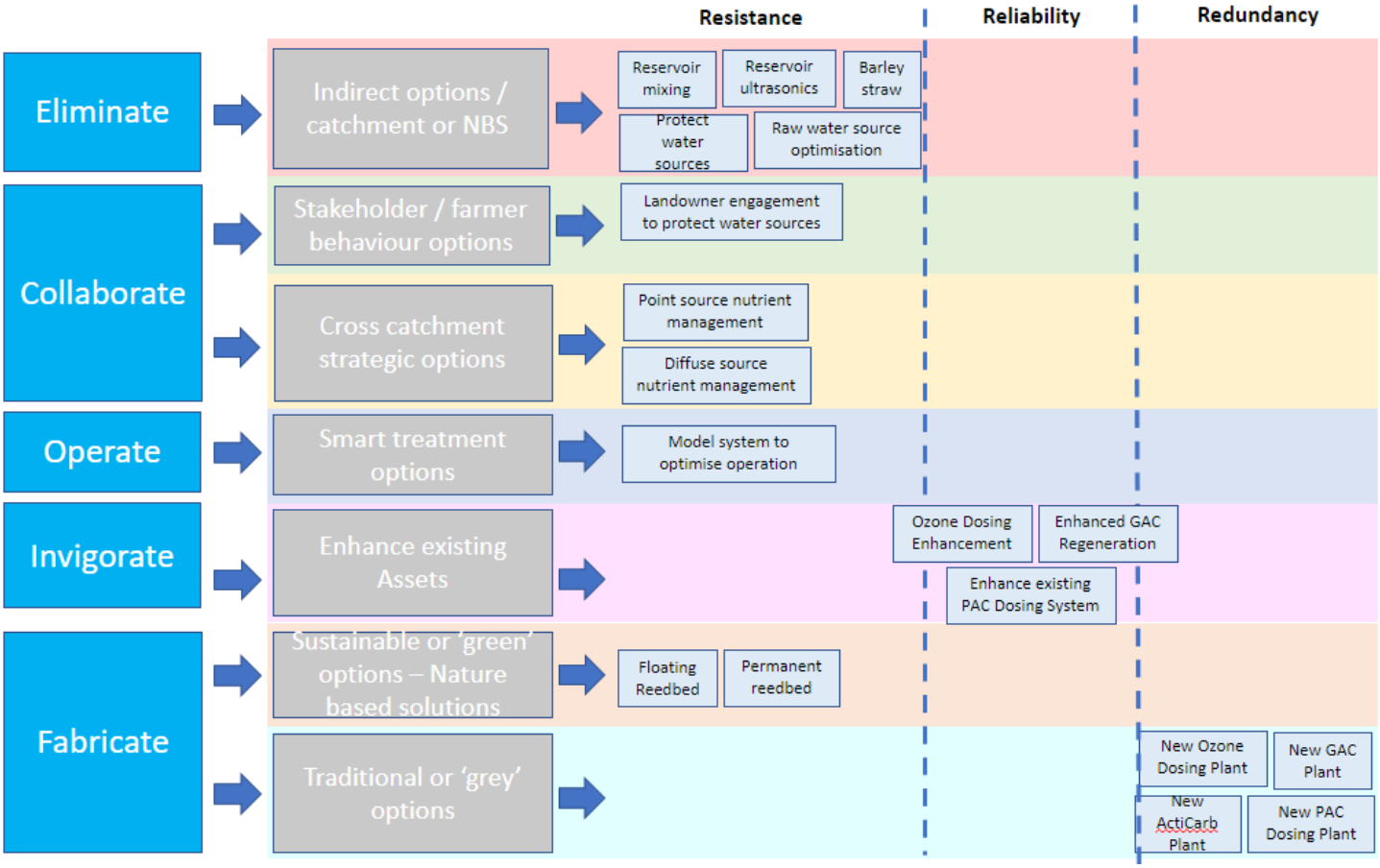
- Resistance – prevent disruption by providing measures to resist the hazard such as options that reduce the likelihood of Geosmin reaching our abstractions points. We identified 11 options that resist the presence of Geosmin in raw water and therefore align with Resistance.
- Reliability – assets designed to operate at and remove higher Geosmin concentrations or operate through periods of prolonged Geosmin concentrations in raw water. We identified three options that can remove Geosmin from raw water and therefore align with Reliability.
- Redundancy – provide backup measures that can be implemented during periods of higher Geosmin concentrations in raw water to ensure continuity of service. We identified four options that can be implemented during periods of high Geosmin concentrations in raw water and therefore align with Redundancy.
- Response and recovery – fast and effective response to, or recovery from, disruptive events caused by high concentrations of Geosmin. We did not identify options that can be used in response to or to recover from high Geosmin concentrations.

Our unconstrained list considers options with differing levels of costs and benefits categorised as follows:

- Eliminate – identification of processes or practices that eliminate the need. In this case, this includes options that reduce Geosmin concentrations in the source water and prevent it from reaching our abstraction points, including the use of reservoir mixing or barley straw.
- Collaborate – working with stakeholders to re-assign the issue or co-fund to address it. Costs can be shared with third parties either to deliver the same or an additional level of social and environmental benefit. In this case, options include working with landowners to protect the water source or working with stakeholders to address point or diffuse nutrient sources in the catchment.
- Operate – this would involve improving our operational management practices to reduce the concentration of Geosmin. However, if the existing WTW processes are not designed to remove Geosmin, optimisation is of limited value. In this case, we have considered looking for opportunities to optimise our operations through modelling the water supply system.
- Invigorate – this would involve investing in existing infrastructure to improve performance. These options will provide an increased level of benefit but may be of a lower cost than fabricate options. In this case, options include optimising existing processes on site such as ozone dosing, GAC, and PAC.
- Fabricate – this would involve investing in new assets to augment or replace existing assets to meet the need. These options are likely to have the highest costs. Green options will have lower carbon and potentially higher biodiversity and amenity benefits. Traditional grey options are likely to have highest certainty that service-related benefits will be realised.

In this case, we have considered fabricating green and grey solutions to reduce Geosmin concentrations in source water, including using reedbeds in the source water, and using new processes at the WTW.

FIGURE 4: THE UNCONSTRAINED LONG LIST OF OPTIONS IDENTIFIED TO ADDRESS THE GEOSMIN NEED, AND THEIR ALIGNMENT TO THE TOTEX HIERARCHY CATEGORIES AND 4RS OF RESILIENCE



3.2. PRIMARY AND SECONDARY SCREENING OF OPTIONS

We have screened our unconstrained list of options for Broken Scar and Warkworth WTWs to determine whether the intervention:

- can guarantee a reduction in Geosmin in raw water to below 9 ng/L in AMP8, and
- is technically feasible.

The outcomes of this primary screening process are summarised for Broken Scar and Warkworth WTWs in Table 6 and Table 7, respectively.

Options that did not satisfy the two criteria were rejected and have been captured in a Rejection Register. Those options that have satisfied the two assessment criteria were carried forward to secondary screening.

Secondary screening of the constrained list of options involved determining the costs and the benefits for each shortlisted option. This was completed to understand whether the options were obviously higher in cost or carbon impact, or would deliver less benefit compared to other options. This process produced a feasible list of options for each need, which is shown in Table 8. We identified two feasible options for Broken Scar WTW; two fabricate options that will provide redundancy to the WTW to manage Geosmin levels in raw water. We also identified one feasible option for Warkworth WTW; an invigorate option that will improve the reliability of the WTW to manage Geosmin levels in raw water.

We have shared the outcomes of our optioneering process with the DWI to seek their support with our approach to improve aesthetic water quality for our customers. In August 2023, we received a letter of support for both sites, stating that the DWI supports our need to install treatment at Broken Scar[11] and Warkworth[12] WTWs to facilitate compliance with the T&O standard for drinking water quality reasons. The DWI also supports us to include the preferred solutions in Table 10 in our Final PR24 Business Plan, and we can provide this letter on request.

Our assessment of benefits for the options is included in Section 3.3.1 and our approach to costing is outlined in Section 4.1. These have then been used to inform the cost benefit appraisal to determine the preferred option, as outlined in Section 3.3.2.

[11] DWI Reference: NES15
[12] DWI Reference: NES7

TABLE 6: THE OUTCOMES OF THE PRIMARY SCREENING PROCESS FOR BROKEN SCAR WTW

Totex Hierarchy	Options		Technically Feasible	Guarantee Geosmin removal in AMP8	Primary Screening Outcome	Resilience approach
Eliminate	1	Reservoir mixing	No	No	Rejected: Raw water reservoir is not the primary source of the Geosmin/MIB, and the River Catchment is not viable for installation of the technology.	Resistance
	2	Protect water sources	Yes	No	Rejected: Improvements in the raw water catchment is unlikely to provide the required benefit within AMP8. Limited catchment control due to river source.	Resistance
	3	Reservoir ultrasonics	No	No	Rejected: Raw water reservoir is not the primary source of the Geosmin/MIB, and the River Catchment is not viable for installation of the technology.	Resistance
	4	Barley straw	No	No	Rejected: Raw water reservoir is not the primary source of the Geosmin/MIB, and the River Catchment is not viable for installation of the solution.	Resistance
	5	Raw water source optimisation	No	No	Rejected: Single river source, therefore not feasible to optimise the raw water source by seasonal alterations in source.	Resistance
Collaborate	6	Landowner engagement to protect water sources	Yes	No	Rejected: Improvements in the raw water catchment is unlikely to provide the required benefit within AMP8 but may be a long-term option to reduce treatment costs.	Resistance
	7	Point source management of nutrients	Yes	No	Rejected: Improvements in the raw water catchment is unlikely to provide the required benefit within AMP8 but may be a long-term option to reduce treatment costs.	Resistance
	8	Diffuse source nutrient management	Yes	No	Rejected: Improvements in the raw water catchment is unlikely to provide the required benefit within AMP8 but may be a long-term option to reduce treatment costs.	Resistance
Operate	9	Model system to optimise operation	Yes	No	Rejected: Improvements in the raw water catchment is unlikely to provide the required benefit within AMP8 but may be a long-term option to reduce treatment costs.	Resistance
Invigorate	10	Ozone dosing enhancement	No	No	Rejected: No existing Ozone dosing system present on-site to be enhanced	Reliability
	11	Enhanced GAC Regeneration	Yes	No	Rejected: GAC alone is unable to meet the required Geosmin/MIB removal from the raw water, therefore additional improvements will not be sufficient requiring additional solution	Reliability
	12	Enhance existing PAC Dosing System	Yes	No	Rejected: No existing PAC plant to enhance.	Reliability

Totex Hierarchy	Options		Technically Feasible	Guarantee Geosmin removal in AMP8	Primary Screening Outcome	Resilience approach
Fabricate	13	Floating reedbed or alternative NBS	No	No	Rejected: Not possible to provide guaranteed removal rates for Geosmin/MIB or benefit in reducing precursors to the Rejected: Geosmin/MIB. Variable level in on-site raw water reservoir would negate possibility to install due to root attachment risk to base.	Resistance
	14	Permanently installed reedbed	No	No	Rejected: Not possible to provide guaranteed removal rates for Geosmin/MIB or benefit in reducing precursors to the Geosmin/MIB. Raw water levels would be variable leading to a challenge in installation also.	Resistance
	15	New ozone dosing plant	Yes	Yes	Carried forward	Redundancy
	16	New PAC dosing plant	Yes	Yes	Carried forward	Redundancy
	17	New GAC plant	Yes	No	Rejected: Existing GAC process is located on-site and unable to meet removal requirements	Redundancy
	18	New ActiCarb Plant	Part	Yes	Rejected: Would be considered an option if PAC dosing had negative impact on existing clarification stage, otherwise considered a higher CAPEX and technically challenging solution compared to PAC dosing into raw water.	Redundancy

TABLE 7: THE OUTCOMES OF THE PRIMARY SCREENING PROCESS FOR WARKWORTH WTW

Totex Hierarchy	Options		Technically Feasible	Guarantee Geosmin removal in AMP8	Primary Screening Outcome	Resilience approach
Eliminate	1	Reservoir mixing	No	No	Rejected: River Catchment is not viable for installation of the technology.	Resistance
	2	Protect water sources	Yes	No	Rejected: Improvements in the raw water catchment is unlikely to provide the required benefit within AMP8 but may be a long-term option to reduce treatment costs.	Resistance
	3	Reservoir ultrasonics	No	No	Rejected: River Catchment is not viable for installation of the technology.	Resistance
	4	Barley straw	No	No	Rejected: River Catchment is not viable for installation of the solution.	Resistance
	5	Raw water source optimisation	No	No	Rejected: Single river source, no option to optimise	Resistance
Collaborate	6	Landowner engagement to protect water sources	Yes	No	Rejected: Improvements in the raw water catchment is unlikely to provide the required benefit within AMP8 but may be a long-term option to reduce treatment costs.	Resistance
	7	Point source management of nutrients	Yes	No	Rejected: Improvements in the raw water catchment is unlikely to provide the required benefit within AMP8 but may be a long-term option to reduce treatment costs.	Resistance
	8	Diffuse source nutrient management	Yes	No	Rejected: Improvements in the raw water catchment is unlikely to provide the required benefit within AMP8 but may be a long-term option to reduce treatment costs.	Resistance
Operate	9	Model System to optimise operation	Yes	No	Rejected: Improvements in the raw water catchment is unlikely to provide the required benefit within AMP8 but may be a long-term option to reduce treatment costs.	Resistance
Invigorate	10	Ozone dosing enhancement	No	No	Rejected: No existing Oxone treatment on-site	Reliability
	11	Enhanced GAC Regeneration	No	No	Rejected: Existing GAC unable to meet the required Geosmin/MIB removal from the raw water, therefore additional improvements will not be sufficient requiring additional solution	Reliability
	12	Enhance existing PAC Dosing System	Yes	Yes	Carried forward	Reliability

Totex Hierarchy	Options		Technically Feasible	Guarantee Geosmin removal in AMP8	Primary Screening Outcome	Resilience approach
Fabricate	13	Floating reedbed or alternative NBS	No	No	Rejected: Not possible to provide guaranteed removal rates for Geosmin/MIB or benefit in reducing precursors to the Geosmin/MIB, river catchment also means not feasible to install.	Resistance
	14	Permanently installed reedbed	No	No	Rejected: Not possible to provide guaranteed removal rates for Geosmin/MIB or benefit in reducing precursors to the Geosmin/MIB, river catchment also means not feasible to install.	Resistance
	15	New ozone dosing plant	No	No	Rejected: Ozone not capable of meeting the required removal on-site for Geosmin/MIB	Redundancy
	16	New PAC dosing plant	Yes	Yes	Rejected: There is an existing PAC plant at Warkworth WTW with limited capacity (not designed for Geosmin removal), therefore enhancing the existing unit to the capacity required to treat Geosmin is the obvious solution in this case.	Redundancy
	17	New GAC plant	No	No	Rejected: Existing GAC process is located on-site and unable to meet removal requirements due to level of Geosmin/MIB, new plant would provide same performance assumption.	Redundancy
	18	New ActiCarb Plant	Part	Yes	Rejected: Would be considered an option if PAC dosing had negative impact on existing clarification stage, otherwise considered a higher CAPEX and technically challenging solution compared to PAC dosing into raw water.	Redundancy

TABLE 8: CONSTRAINED LIST OF OPTIONS TO ADDRESS THE GEOSMIN NEED AT OUR PRIORITY SITES

Totex Hierarchy Categories	Options		Resilience approach	Priority Sites
Invigorate	12	Enhance existing PAC dosing system	Reliability	Warkworth WTW
Fabricate	15	New ozone dosing plant	Redundancy	Broken Scar WTW
	16	New PAC dosing plant	Redundancy	Broken Scar WTW

3.3. BEST VALUE

3.3.1 Benefit scoring

For each option carried forward to this stage we have completed a benefits assessment using our Value Framework[13] which contains a wide range of benefits that reflect measures relating to performance commitments or other social and environmental values. Our Value Framework is embedded into our portfolio optimisation tool, Copperleaf. Table 9 shows the range of benefits (value measures), including their quantification and monetisation values, we have used for the assessment of the shortlisted options. These include improved water aesthetics and carbon emissions. Our assessment of benefits has been used to inform our cost benefit options outlined in Section 3.3.2.

TABLE 9: RANGE OF BENEFITS IDENTIFIED FOR RAW WATER DETERIORAITION

Value measures	Description	Unit	Value	Aligned to a performance commitment?
Improved Water Aesthetics	Cost of improving appearance, taste and smell of water	£/Number of Customer Contacts (Banded)	£41,766 [14] £6,661 [15]	Yes
Operational Emissions	t/CO_2e / year	tCO_2e	£256.20 [16]	Yes
Embedded Emissions	t/CO_2e / year	tCO_2e	£256.20 [14]	Yes

For the benefits assessment, first we score the impact of continuing business as usual and then we score each of the relevant options. Benefits are scored over time for a 30-year time horizon. This scoring considers the certainty of benefits being realised for different types of options.

The three value measures in Table 9 have helped us to differentiate between options for Broken Scar WTW. Using the Improved Water Aesthetics value measure, we have assumed that benefits will be realised as soon as the solutions (technologies) are commissioned, which reflects the certainty of benefits to be delivered by these established technology options. Therefore, benefit will be realised through a reduction in the number of customer contacts. We have assumed both options will be 100% effective and therefore will reduce customer contacts to zero. As the two solutions will be implemented in different years, due to differences in implementation time, this is reflected in how soon benefit will be realised. Therefore, the PAC option is expected to deliver Improved Water Aesthetics one year earlier than the ozone option.

Additionally, the PAC option will result in less carbon emissions (435 t/CO_2e) compared to the ozone option (2,305 t/CO_2e) over the 2025-30 period. This is reflected in our Operational and Embedded Emissions value measures. Over a 30-year

[13] Northumbrian Water Limited Value Framework Definition Document, v1.6, Copperleaf Technologies Inc., 2002
[14] £ value for appearance category with 0-1,000 customers affected
[15] £ value for smell category with 0-1,000 customers affected
[16] £ value per tonne of CO_2e in 2025/26, annual increase (varying rate) reaching £378.6/t CO2e in 2054/55

time horizon, the ozone option is expected to result in 13 times more carbon emissions compared to the PAC option. For both options, we have assumed there are capital replacement needs every 10 years. The higher emissions for ozone are due to having higher capital and higher operational emissions, as a result of the types of materials and power requirements of this option. Therefore, the value measures we have used highlight that the PAC option will deliver greater benefits to our customers and the environment.

The three value measures in Table 9 have been used to assess the benefit from enhancing the existing PAC dosing system at Warkworth. Using the same assumptions as for Broken Scar, that the option is expected to reduce customer contacts to zero as soon as it is commissioned, we expect the benefit to be realised in the third year of the AMP. Additionally, the carbon emissions associated with enhancing the existing PAC are 1,306 t/CO_2e over the 2025-30 period; naturally these are less than for a new PAC at Broken Scar, due to the extent of existing infrastructure that will be used.

3.3.2 Cost benefit appraisal to select preferred option

For each of the feasible options we have carried out a robust cost benefit appraisal within our portfolio optimisation tool to select the preferred option. This calculates a net present value (NPV) over 30 years, in accordance with the PR24 Guidance, and the cost to benefit ratio for each option. The ratio is calculated by dividing the present value of the profile of benefits by the present value of the profile of costs over the appraisal period of 30 years.

Costs and benefits have been adjusted to 2022/23 prices using the CPIH[17] Index financial year average. The impact of financing is included in the benefit to cost ratio calculation. Capital expenditure has been converted to a stream of annual costs, where the annual cost is made up of depreciation / regulatory capital value (RCV) run-off costs and allowed returns over the life of the assets. Depreciation (or run-off) costs are calculated using straight-line depreciation over the appraisal period. To discount benefits and costs over time, we have used the social time preference rate set out in The Green Book[18].

The NPVs generated by our portfolio optimisation tool are included in Table 10. For Broken Scar, the NPVs for the two options demonstrate that implementing the 'New PAC dosing system' option will deliver the greatest value as it has the highest NPV (-£6.181m). At Warkworth, the solution to 'upsize PAC dosing system' has an NPV of -£5.904m. These NPVs have been informed by the monetised benefits only (Embedded and Operational Emissions) discussed in Section 3.3.1 and option costs as included in Section 4.2.

We are mindful that our benefits assessment has been limited by available data at this time, and so our NPV is not a true reflection of all benefits that will be delivered through these options, particularly improvements to water quality. However, given the difference in the carbon emissions between the options for Broken Scar, as discussed in Section 3.3.1, we believe the NPV showing greater benefit from the 'New PAC dosing system' is relevant. Therefore, our preferred option to address

[17] Consumer Prices Index including owner occupiers' housing costs.
[18] The Green Book: Central Government Guidance on Appraisal and Evaluation, HM Treasury, 2022

Geosmin at Broken Scar WTW is the 'New PAC dosing system' option. Our preferred option to address Geosmin at Warkworth WTW is the 'Upsize PAC dosing system' option.

TABLE 10: BENEFIT TO COST RATIO AND THE PREFERRED OPTIONS TO ADDRESS THE GEOSMIN NEEDS

Site	Option	Net Present Value (30 years) (£)	Benefit: Cost	Type of Option
Broken Scar WTW	New Ozone Plant	-23.534m	0.01	Alternative
	New PAC dosing system	-6.181m	0.04	Preferred
Warkworth WTW	Upsize PAC dosing system	-5.904m	0.04	Preferred

We note that the NPV for all options is negative, which would normally suggest that we should not select any of the options. However, we must deliver these projects to meet our obligations to deliver clean, wholesome water.

3.4. THIRD PARTY FUNDING

No opportunities for third party funding have been identified for the chosen interventions, as they are established engineered solutions to address T&O needs and will reside on sites which are not open to others. Therefore, these options are unlikely to attract funding from third parties. We will continue to explore opportunities for third party funding in the delivery of the projects.

3.5. DIRECT PROCUREMENT FOR CUSTOMERS

We assessed these investments against the Direct Procurement for Customers (DPC) guidance (see our **assessment report**, NES38). We noted that they would not pass under the 'size' test, as they have a whole life cost of less than £200m. We considered how this could be bundled together with other improvements at treatment works across our business plan, but these are not discrete investments. We concluded that DPC was not appropriate.

3.6. DELIVERABILITY ASSESSMENT

We have carried out a deliverability assessment for our options to provide certainty that our short-listed options are deliverable during AMP8. This has considered:

- The technical feasibility of implementing an intervention – all the short-listed options are technically feasible to implement.
- The certainty that benefits for each option will be realised – this has been assessed as part of the likelihood scoring in our benefits assessment. More information on our benefits assessment is included in Section 3.3.1.
- Lessons learned from other projects to encourage efficiency – we have been learning through delivery of PAC at Ormesby WTW, summarised in Section 2.3.

- The confidence with which we can deliver by 2030 – the preferred PAC solution for Broken Scar WTW is modular and manufactured off-site as a self-contained dosing unit, thus reducing cost uncertainty.
- Early start to make sure delivery is feasible by the due dates.

Our deliverability assessment has concluded that we can deliver any of our short-listed options in the 2025-30 period.

3.7. CUSTOMER VIEWS INFORMING OPTION SELECTION

Our customers consider water quality to be a high priority (for both compliance risk index and water quality contacts, see our **prioritisation of common PCs**, NES44).

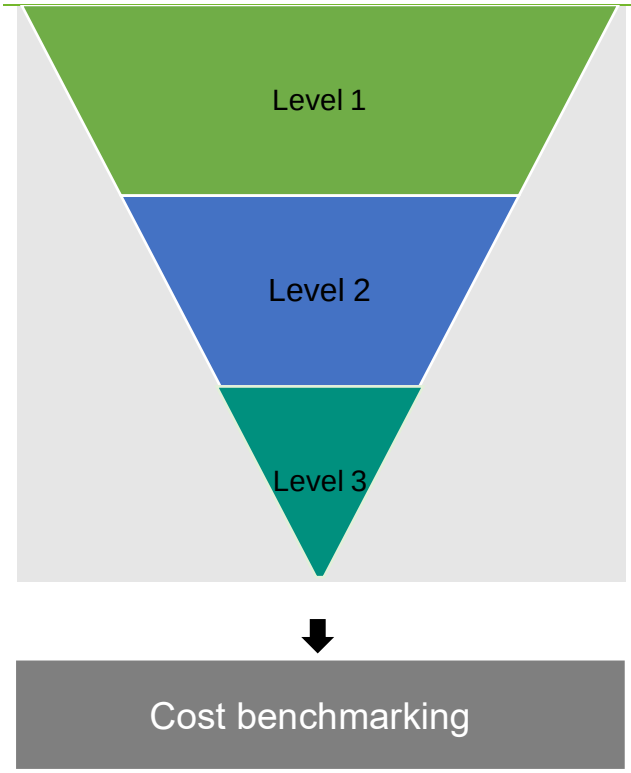
Our customers expect us to meet our obligations to provide wholesome drinking water, and we must make these investments to do so (see Section 2 on the statutory need for these investments). We have not asked customers about the technical detail of dosing at our treatment works.

4. COST EFFICIENCY

4.1. COST METHODOLOGY

A full description of our costing methodology is contained in appendix A3 - Costs (NES04). We have used a three-level estimating approach for developing our PR24 costs, as outlined in Figure 5. Our short-listed options have been costed to Level 2. As these are relatively low complexity projects this level is appropriate for a price review submission as it is sufficient to understand that the interventions can be delivered within the cost at a programme level. A Level 3 estimate would require a level of detailed design to be carried out, which would incur significantly more cost which is not appropriate until delivery is confirmed.

FIGURE 5: PROCESS COST ESTIMATION



Level – 1 (confidence: – 50% to +100%)

Costing is carried out using Northumbrian Water's iMOD Express or Costing Tools, which utilise costing curves at the asset level. This enables order of magnitude estimating for rapid optioneering.

Level – 2 (confidence: - 50% to + 50%) – Chosen Approach

Costing is carried out using Northumbrian Water's iMOD cost estimating system, which utilises costing curves for the main items of scope. This provides detailed cost estimates for main scope items.

Level – 3 (confidence: - 20% to +30%)

Detailed bottom-up cost estimates are developed for all items within scope. This requires detailed scoping to enable more detailed cost to be established.

Cost benchmarking

We have benchmarked 100% of the preferred options against the available cost curves from other companies. Further detail is provided in Section 4.3.

Options costing for Geosmin solutions at Broken Scar WTW and Warkworth WTW has been carried out to Level 2, using our iMOD system. Our iMOD system is an engineering scoping and cost estimating software system. It provides an integrated platform for project scope definition, whole life costing and tender evaluation.

There are two estimating approaches within the system, iMOD Express and iMOD Engineering Scoping and Estimating.

iMOD Express is an asset level cost triage system that provides high-level CAPEX and OPEX estimation based on a single overarching cost driver. We use this extensively for Level 1 estimations. We used the full iMOD estimation package to develop Level 2 costs for our short-listed Geosmin options.

The iMOD Engineering Scoping and Estimating comprises a suite of 50 engineering scoping models and a large and detailed cost database containing many thousands of costing data-points on a range of components and assets. With a minimum of input criteria that is readily known at project inception, the system can provide a detailed CAPEX, OPEX and whole life costing for a range of business issues by developing relevant cost curves for the investments in question. The cost estimates have been produced using Asset Policy Group (APG) Water Treatment specific cost curves for Process, Component, Contract, and Project Overheads.

4.2. PREFERRED OPTION COSTS

The iMOD Level 2 costs generated for the preferred options at Broken Scar and Warkworth WTWs are shown in Table 11 below. Capex includes the engineering scope cost and overheads. We have assumed we can deliver these options in the first two years of AMP8. Opex costs include power and chemicals. We have assumed opex costs will be required for the last three years of AMP8, and onwards, following installation of the options by the end of year 2 of the AMP.

As the PAC plant at each site would only be required to operate for a proportion of the year, generally during the summer period when algal risk and therefore Geosmin presence is higher, opex costs have been adjusted accordingly. This has been based on sample analysis from the last five years, which has been used to estimate the number of days per year the PAC unit would be expected to run. Table 11 shows both the annual opex, and the total AMP8 opex based on our estimated programme to deliver both solutions by the end of year 2.

TABLE 11: IMOD COSTS AT BROKEN SCAR AND WARKWORTH WTWS

Site	Preferred Option	Capex – excl. OH + risk (£m)	Capex – inc. OH + risk (£m)	Annual Opex (£m)	AMP8 Total Opex (£m)	Totex (£m)
Broken Scar WTW	New PAC dosing system	1.186	3.682	0.192	0.576	4.259
Warkworth WTW	Upsize PAC dosing system	0.986	3.177	0.204	0.612	3.789

4.3. COST BENCHMARKING

A sample of Raw Water Deterioration project estimates produced as part of the PR24 costing process have been benchmarked against comparable water and wastewater companies. As part of this exercise, both Broken Scar and Warkworth Geosmin PAC dosing scheme costs have been compared against industry data for the same type of solution.

The benchmarking compares our generated estimates against five comparable water and wastewater companies in England and Wales. A mean average from company data has been used as the benchmark with a 25th and 75th percentile provided as a suitable range. The costs comparisons have been calculated using the latest cost curve data from each company, and reflect the same data used by each company to build its PR24 submission. The costs generated by each cost curve are based on appropriate sizing metrics – in the case of PAC dosing, the cost models are based on WTW flow to be treated in megalitres per day (MLD).

The benchmarked costs have been adjusted for inflation using CPIH and have a price base of Q2 2022.

Table 12 shows the outcome of the cost benchmarking analysis for the two sites. The analysis shows our cost estimate for Broken Scar WTW is 22% (£0.337m) cheaper than industry benchmark, and Warkworth is 25% (£0.198m) above. However, at programme level, our cost estimate for delivering the two solutions is 6% more efficient than the benchmark cost.

TABLE 12: PAC OPTION COST BENCHMARKING OUTCOMES

Site	Northumbrian cost	Benchmark cost	25th percentile	75th percentile	Delta	Delta %
Broken Scar WTW	£1,185,763	£1,522,886.14	£1,218,308.91	1,979,751.98	-£337,123.06	-22%
Warkworth WTW	£986,023.39	£788,168.92	£630,535.13	£1,024,619.59	£197,854.47	25%
Total	**£2,171,786.39**	**£2,311,055.06**			**-£139,268.59**	**-6%**

In addition to benchmarking project scope, we conducted analysis of client and contractor indirect costs, comparing our own project and contract overheads to data provided by the same six comparator water companies. Table 13 shows that our indirect costs are calculated as 63.40% of direct costs compared to the industry benchmark of 73.86%. Our indirect costs are therefore 10.46% below the industry benchmark. Our estimate also includes a 10% uplift for risk and 30% for estimating uncertainty.

TABLE 13: INDIRECT COST BENCHMARKING OUTCOMES

Indirect cost type	Northumbrian cost	Benchmark cost	Delta
Total Contractor Indirect	36.88%	48.01%	-11.14%
Total Client Indirect	26.52%	25.84%	0.68%
Total Project Indirect	63.4%	73.86%	-10.46%

5. CUSTOMER PROTECTION

5.1. PERFORMANCE COMMITMENTS

Performance commitments (PCs) incentivise water companies to improve performance and maximise outcomes for customers and the environment. We expect this enhancement case to improve our performance against the "customer contacts about water quality" performance commitment, though this is likely to be a negligible amount. This is because the case is about proactively preventing a deterioration in performance – in Table 4 above, we showed that there are currently about 7 contacts per year. In Table CW15 in our business plan tables, we estimate that there will be 10 fewer contacts per year, with an impact of around £27k on outcome delivery incentives (ODIs) (reflected in our performance commitment). We also expect this enhancement case to contribute to preventing a deterioration in customer measure of experience (C-MeX) by reducing water quality contacts.

If we did not carry out this work, there would be some impact on our operational greenhouse gas emissions. We estimate both the embedded and operational carbon emissions in Table CW15.

In **A4 – Outcomes** (NES05), we set out our performance commitment for water quality contacts.

5.2. PRICE CONTROL DELIVERABLES

Our approach to determining Price Control Deliverables (PCD) is outlined in Section 12.3 of **A3 – Costs** (NES04). In Table 14 below, we assess our raw water deterioration enhancements to test if the benefits are linked to PCs, against Ofwat's materiality of 1%, and to understand if there are outcome measures that can be used.

Our assessment shows that the outcome of this enhancement case is entirely covered by PCs. Although the investment does not contribute to a significant increase in performance, if we did not carry out this investment then we would be penalised under the water quality contacts ODI, at a rate of around **£3,170** per contact (see **A4 – outcomes**, NES05). In addition to the impact from ODIs, we have shown that there are historic penalties for non-compliance for other companies when they have failed to meet Geosmin standards.

TABLE 14: ASSESSMENT OF BENEFITS AGAINST THE PCD CRITERIA

Enhancement scheme	Benefits linked to PC?	Materiality	Possible outcomes?
Raw water deterioration (NES21)	Fail – impact on unplanned outage and taste/odour complaints	Fail – 0.2%	Outcome covered by performance commitments.

This is also not material at the 1% level, with no clear aggregation possible with projects with a similar purpose.