Appendix 14a:

Drinking Water Quality DWI Submission

YorkshireWater

Long-term Statement on Drinking Water Quality

Yorkshire Water Services Ltd

May 2018

Executive Summary

This document has been produced to meet the DWI requirement for “a concise statement that sets out significant new future risk mitigation measures to provide assurance that drinking water risk assessments include a long-term view”. It articulates our plans to deliver improved water quality for our customers and assure a clean, wholesome, and sustainable supply of drinking water. We will plan to maintain and enhance the resilience of our services so that customers can rely on them.

This forms one of our Strategic Goals and is a key commitment to our customers.

We are developing a long-term water strategy which focuses on water quality and acceptability as well as on its’ water resources. Our PR19 submission to the Drinking Water Inspectorate and the Draft Water Resource Management Plan were developed in line with the principles used to develop that strategy.

Our approach is fundamentally based on outcomes that were developed with customers, and derived from what they told us was important to them:

- We provide you with water that is clean and safe to drink
- We make sure that you always have enough water

These were developed with customers five years ago, and over recent years we have built on this intelligence with nearly 19,000 customer conversations across a wide variety of formats. These conversations have helped us understand more about what is important to our customers now and in the future. Our customers told us that they want us to stop failures in service from affecting their lives. For this reason, we need to ensure that our water supply assets and catchments are resilient and sustainable, and can deliver both the quantity and quality customers require.

We have looked at what is required to allow Yorkshire Water to provide drinking water services to its customers from both Resilience and Drinking Water Safety Planning approaches; we have also undertaken a source to tap review of our assets, their performance, and what our future requirements of them are. This allowed us to look at the issues and solutions both at a whole business perspective, and down to water supply system specific considerations.

In developing our understanding of future challenges, the Drinking Water Safety Plan (DWSP) approach for managing risks to water quality and sufficiency is well established. This was used to develop our AMP7 specific programme, and in preparing this statement, along with the potential requirements through to AMP11 and beyond. Alongside this we undertook a review of what we expect the water supply needs of our customers to be in 2045, and in response to this scenario identified what our assets need to be able to deliver to achieve them; this led to the development of a set of key principles focussed on the source to tap delivery of services.

We perceive increasing challenges to the quality of raw waters available to abstract, as a result of both human activity and natural impacts. In response to these challenges we will move toward a catchment-based approach to managing hazards by implementing interventions which prevent them from impacting water sources, or provide for their attenuation upstream. Where new treatment processes are the only means of delivering safe, acceptable water for our customers, we will choose the intervention with care to minimise carbon impacts, and build the assets which deliver multiple benefits, and with asset lives which match the likely extent of the risk.

We will implement an enhanced programme of asset management and maintenance activities on our larger, strategic treatment assets and trunk main network. This will ensure resilience against the key challenges of climate change and population growth, mitigate concerns about possible terrorism on our water supplies, prevent service failures impacting on customers lives, improve water quality, and reduce leakage.

We will continue our efforts to improve customer acceptability of water, especially in respect of discolouration and taste & odour. This will be delivered through a balanced mix of mains flushing, lining and replacement to prevent burst mains, issues with water quality, and disruption to customers. We will implement new data systems so we can intervene proactively to mitigate problems such as leaks or bursts much earlier. Population growth is an added pressure we must plan for in the future by laying or adopting leak-free networks.

We will continue and accelerate activities to remove lead from the connections to customers' homes & businesses, and will work to develop the strategies and techniques needed to deliver this. This requires a joined-up approach between the Water industry, Government, Local and Health Authorities, and building owners, and we will play our part in these conversations.

We have undertaken reviews to better understand the resilience of our water supply services, at a Regional, Company-wide level, along with more detailed reviews of water supply systems in a local context. We will use the outputs from these reviews to develop plans to enhance resilience across our catchments, treatment facilities, and water network. In doing this we will seek to use appropriate technology and innovation to deliver improvements, whilst being mindful of the potential costs for customers.

Our strategy will continue to evolve as more evidence is gathered; and we are looking to re-engage with the Inspectorate in the near future to develop more detail and evidence, as we seek to secure water quality for the future for our customers.

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1.0 Our Approach to Developing a long-term strategy for Drinking Water Quality

1.1 Our Strategic Direction 2018

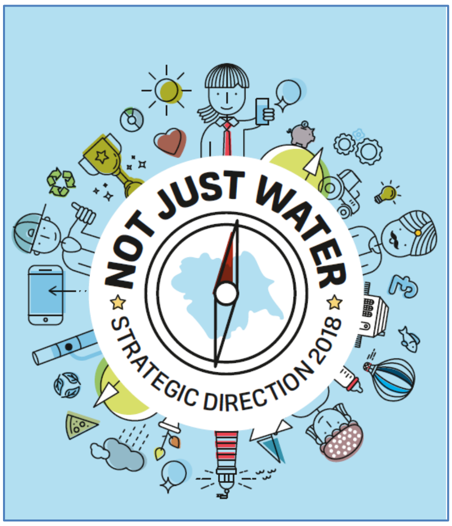


Figure. 1: Strategic Direction 2018 Document.

Since we submitted our Periodic Review (PR19) plans to Drinking Water Inspectorate (DWI) in December 2017, Yorkshire Water has published a long-term strategic direction document for consultation. This is part of our ongoing conversations with customers and other stakeholders on a wide range of criteria which affect the services we deliver.

The document "Not Just Water – A Strategic Direction 2018" begins by outlining the scale of our operations and how these deliver service to customers. It aims to demonstrate how our ability to produce sufficient, high quality, great tasting water is dependent on the integrated management of the catchments that gather water, the reservoirs, rivers and aquifers that store and transport water to our abstractions, our water treatment facilities, the pipe networks and service reservoirs which transport and store treated water, and finally the pipework that connects our systems to our customer's homes and businesses. Our customers have clearly told us that their number one priority is a reliable supply of clean, good quality water. They need to know that their water supply is secure, wholesome and sustainable. Our customers also want us to stop failures in service from affecting their lives. We need to ensure that our water supply system is resilient. Our customers' priority of a reliable supply of clean, good quality water is reflected in the

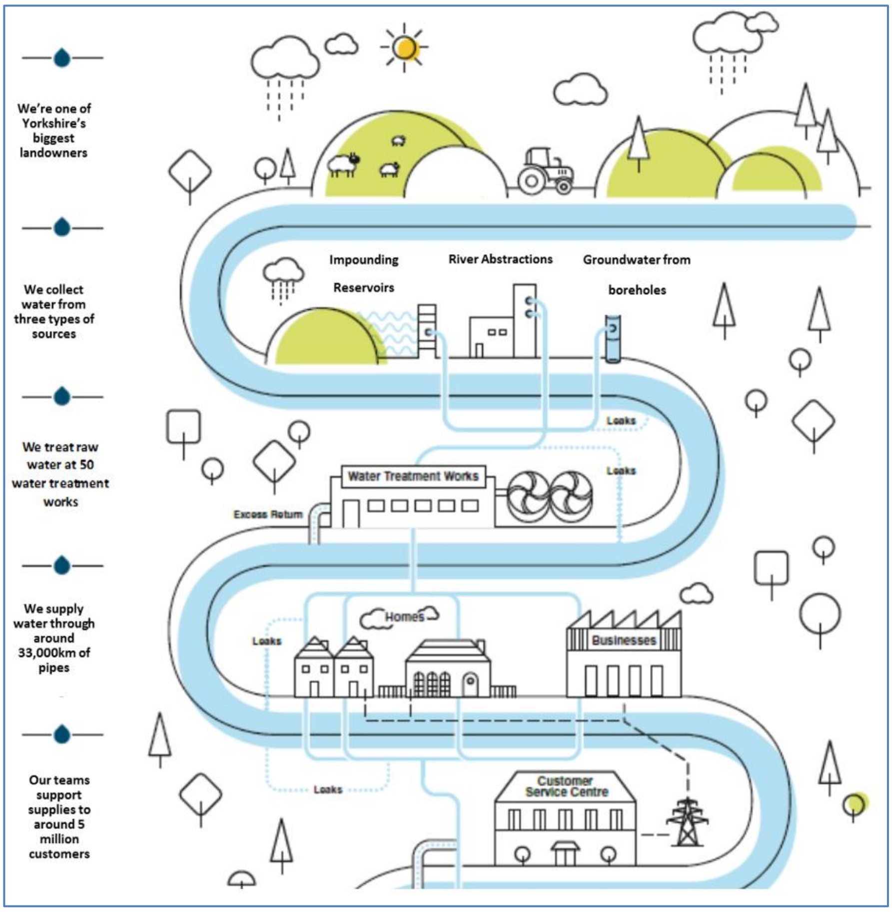


Figure. 2: Source to tap graphic from the Strategic Direction 2018 document.

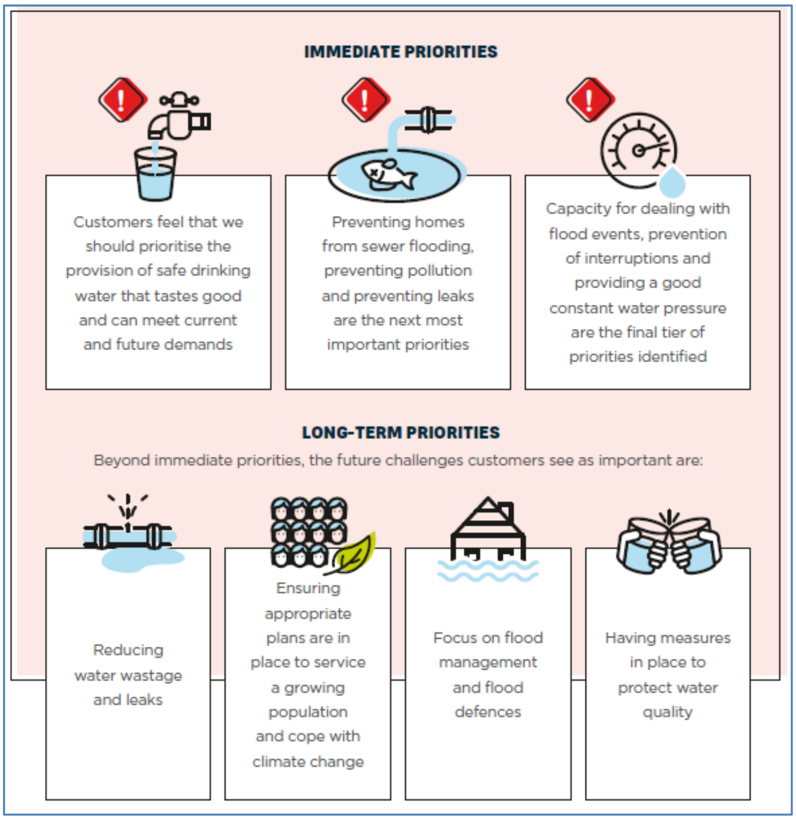


Figure. 3: Yorkshire Water strategic priorities.

legislation and regulation for the water industry, which requires us to supply 'wholesome' drinking water quality that is acceptable to consumers. "Wholesome" is defined in Regulation by strict standards for a wide range of substances, organisms and properties of water, and by its' acceptability to customers. The standards are set to be protective of public health, and, the definition of wholesome reflects the importance of ensuring that water quality is acceptable to consumers, for example in terms of its appearance and taste & odour.

Building on our PR19 submission to the DWI this document is a demonstration of our thinking toward meeting our customer's priorities for the future. It describes how we will protect and deliver improved drinking water quality to our customers in the face of challenges such as population growth, climate change, raw water deterioration, pesticide usage in the environment, and the impact of lead pipes connecting a significant number of customers to our drinking water supply network.

As part of our engagement with and commitment to our customers we have set ourselves "5 Big Goals", which are:

- **CUSTOMERS:** We will develop the deepest possible understanding of our customers' needs and wants and ensure that we develop a service tailored and personalised to meet those needs.
- **WATER SUPPLY:** We will always provide you with enough safe water, we will not waste water, and always protect the environment.
- **ENVIRONMENT:** We will remove surface water from our sewers and recycle all wastewater, protecting the environment from sewer flooding and pollution.
- **TRANSPARENCY:** We will be a global benchmark for openness and transparency
- **BILLS:** We will use innovation to improve service, eradicate waste and reduce costs so no one need worry about paying our bill; we will not waste money.

1.2 Goal Two: Water Supply

Water is essential not just for our immediate use for drinking and washing. It is also essential for producing food, generating energy and creating products like our cars and computers. It's needed for our hospitals, our schools and for the companies that create such a vibrant economy in Yorkshire. Our customers have consistently told us that the thing that is most important to them is a reliable and sustainable supply of high quality drinking water. The population is increasing, and the economy in Yorkshire is growing. Climate change brings uncertainty over future supply and consistency of rainfall patterns. We want to always have enough water in Yorkshire.

Figure. 4: Goal two of five strategic goals.

1.3 Key Deliverables for Goal Two

- We will be self-sufficient in water – but we would facilitate transfers through Yorkshire to add resilience to national water supply strategies.
- We will reduce leakage by 40% by 2025, this will make our own supplies more resilient and give us choices about our future decisions.
- We recognise the impact of interrupting water supplies through our conversations with our customers and we will significantly reduce supply interruptions over the next three years. We are looking to become a leader in this area.
- Overall this will mean that our average interruptions will reduce from 9.47 minutes in 2016, to two minutes by 2025.
- We will work with industry to offset 5% of current demand on drinking water with non-potable water, creating enough extra drinking water for 4,000 new houses without abstracting any more water from the environment.
- We will avoid additional investment in water treatment works (WTWs)by managing our land and influencing others to ensure that water captured is the best quality.
- We will work with customers and other stakeholders to participate in reducing consumption overall in Yorkshire.

1.4 How We Will Deliver Goal Two

- We will not harm the water environment by abstracting too much water.
- We will reduce wasted water by tackling leakage. This also means we will use less chemicals and energy in water treatment and distribution.
- We will avoid additional investment in water treatment as the population grows which will help keep bills low.
- By managing land for water, we will capture more carbon, enhance biodiversity and the people and visitors of Yorkshire can continue to enjoy our beautiful environment.

We have also assessed the ability of our WTWs to support the delivery of our Water Resource Management Plan (WRMP), to ensure we can treat enough water at the right quality in the long-term. The WRMP requires us to understand where we currently have seasonal raw water challenges that can require a reduction in flow through the WTWs to protect water quality. Where future risks are inferred by trends in raw water quality deterioration, we have forecast the point at which risks become intolerable. This allows us to proactively intervene and informs our long-term planning, allowing in many cases a catchment first approach to managing risks to water supplies, rather than installing ever more complex treatment systems.

1.5 Building on the context of AMP7 Planning

This document is part of our developing long-term strategy which will continue to evolve as more evidence is gathered; and we are looking to re-engage with the Inspectorate in the future to develop more detail and evidence to secure water quality for the future for Yorkshire.

1.5.1 Summary of PR19 submission – December 2017

Our submission to the DWI was a key component in meeting our customers' priorities. It forms part of the suite of submissions to our regulators, setting out our long-term plans but specifically planning for the period 2020-2025. It describes how we will protect and deliver improved drinking water quality to our customers. Our forecasts indicate that there are 60 water sources where catchment only interventions are the most appropriate to manage the risk of raw water deterioration in the medium and long-term. Our catchment programme covers a range of specific water quality parameters, including colour arising from peat degradation, pesticides, nitrate and saline intrusion on reservoir, river and groundwater sources. We plan to invest circa £9 million in upland catchment activity in the period 2020-2025, along with circa £7 million on reducing the risk of metaldehyde entering our rivers.

There are six WTWs where we propose to undertake targeted enhancement of the water treatment process to deliver long-term protection of drinking water quality. These are subject to risks which arise from ongoing deterioration in raw water quality, which we forecast will continue. These interventions are supported by long-term catchment management proposals within the Water Industry National Environment Programme (WINEP) to enhance the sustainability of the solutions. This enhancement activity is estimated to cost £75 million above our ongoing base maintenance costs. We are seeking DWI support for this additional investment to secure long-term drinking water quality.

We propose a long-term approach to reduce and eliminate exposure to lead. In the period 2020-2025, we propose activity to ensure that we reduce the risk of lead exposure to vulnerable customer groups, including those requiring continuous supplies and those registered for home dialysis. We also propose targeted activity to reduce exposure to lead in schools and nurseries across Yorkshire. We intend to undertake research and development activity to "extend the length capability of lining" and investigate novel approaches to lead pipe replacement. The overall costs associated with the removal of lead risk are capped at £15 million.

We also plan to achieve a reduced risk of unacceptability of water to our customers, recognising that the aesthetic reduction in quality undermines our customer's confidence in our service. We intend to continue to reduce the risk of discoloured water through the deployment of a range of existing and innovative techniques to prevent significant re-accumulation of material in the distribution network.

Table 1: Overview of proposed risk reduction measures for Drinking Water Quality.

Scheme Name	Driver	Capex (£m)	Opex (£m/yr)	Best Technical Solution	Manages risk to customers	Lowest WLC
Lead (Regional)	Lead risk reduction	15.0	0.0	Y	Y	Y
Tophill Low WTW	*Cryptosporidium;* taste & odour	16.3	0.4	Y	Y	N
Chellow WTW	Colour (DBPs); run to waste; turbidity	23.9	1.1	Y	Y	N
Embsay WTW	Colour (DBPs); turbidity, manganese	8.0	0.1	Y	Y	Y
Fixby WTW	Colour (DBPs); turbidity	5.6	0.04	Y	Y	Y
Sladen WTW	Colour (DBPs); run to waste; turbidity	14.6	0.2	Y	Y	N
Oldfield WTW	Colour (DBPs); turbidity	6.1	0.1	Y	Y	N
Total		89.5	1.9			

2.0 What have we considered in developing our long-term plans?

2.1 Overview

The development of his document contributes to our wider long-term planning as a Company and our consideration of resilience in particular. It also contributes to meeting elements of: -

- The Defra *Strategic policy statement to Ofwat: incorporating social and environmental guidance meeting Ofwat PR19 Methodology*
- The Environment Agency and Natural England *Water industry strategic environmental requirements (WISER) Strategic steer to water companies on the environment, resilience and flood risk for business planning purposes*

There are a number of cross cutting themes which interact in delivering wholesome and resilient water supplies to customers, with innovation and multi-sector collaboration at the heart of delivering resilience, addressing the impacts of climate change, population growth, ensuring great customer service and affordability, and environmental protection and enhancement. These themes are expressed in this document and will be a significant feature of our business plan submissions for PR19 and subsequent reviews.

We have looked at what is required to allow Yorkshire Water to provide drinking water services to its customers from both Resilience and Drinking Water Safety Planning approaches; we have also undertaken a source to tap review of our assets, their performance, and what our future requirements of them are. This allows us to look from a whole business approach, and funnel down to water supply specific considerations. The link of our future strategy to the Drinking Water Safety Plan (DWSP) approach for managing risks to water quality and sufficiency is well established, and was used to develop our Asset Management Plan (AMP7) specific programme, along with the potential requirements through to AMP11 and beyond. We also undertook a review of what we expected the water supply needs of our customers to be in 2045, and in response to this what our assets need to be able to deliver to achieve them; this led to the development of a set of key principles focussed on the source to tap delivery of services.

2.2 Resilience and our long-term strategy

Resilience has long been a priority for us because we know the significant impacts that can result from disruption to public water and waste water services. The reliability of our essential services is critical to economic growth, environmental protection, and ultimately to human life and livelihoods. Yorkshire's public water and waste water services, and the Yorkshire Water business that manages them, are all demonstrably highly resilient. The ultimate measure of our resilience is a long-standing absence of interruptions to water and waste water services.

Customers in Yorkshire have had no restrictions to their public water service since the drought in 1995 and 1996, despite several more extreme dry periods since then. We have also maintained water supplies throughout the various severe floods in Yorkshire over recent years. We have maintained supplies by using the flexibility we built into Yorkshire's supply network, and through our mature and tested operational procedures and emergency planning. However, we can never be complacent. Maintaining levels of resilience is an ongoing process which we keep under continual review so that we can effectively respond to changing circumstances, such as climate change, population growth and the financial environment. For example, we have recently taken steps to improve our financial strength by reducing our gearing and protecting our credit ratings so that we always have secure access to low cost loans to fund needed investments.

We ensure the ongoing resilience of Yorkshire's water and waste water services, and all the critical functions that enable the business to deliver these services securely for the long term, through our extensive and ongoing planning process.

Our planning process highlights the latest developments for management action, including, for example, a sharp rise in the number of cyber-attacks trying to access our data and systems. We have undertaken extensive and innovative engagement with our customers and stakeholders to help shape our approach to resilience. For example, our customers have consistently told us that the most important thing to them is a reliable and sustainable supply of high quality drinking water. Yorkshire's efficient, and resilient water resources approach to drought conditions gives our business the ability to manage a wide range of other shocks and stresses.
We have worked with international resilience experts at Arup to develop a new resilience framework to help us to ensure our plans are based on an extensive assessment of risks and opportunities to our corporate, financial and operational resilience.

2.3 Arup review of High level resilience

This helped develop a comprehensive and repeatable process that uses:

- Updates to our previously existing approaches, such as the climate change strategy and risk assessment we introduced in 2014 and updated for our latest Adaption Report to Government and our strategic risk framework.
- The best available evidence, including granular risk and resilience quantification studies and tools for all areas of priority, such as our above ground assets, pipe bridges, sewer network and bio-resources.
- Our new cutting-edge six-Capitals optimisation system, known as the Decision-Making Framework (DMF).
- International best practice from leaders in resilience, including: Hull community approach and the City Water Resilience Framework pilot with the Rockefeller Foundation.

The Arup review covered all elements of the Kelda & Yorkshire Water businesses, broadly split into the key areas of Financial, Corporate, and Operational resilience. The key aims were to allow the visualisation of the inter-relationships which allow our businesses to function effectively, and balance potentially conflicting objectives.

The following graphic provides an overview of the Corporate Resilience systems which are appropriate to this strategy; Later in the document we introduce the resilience systems for Land & Catchments, Water Resources &

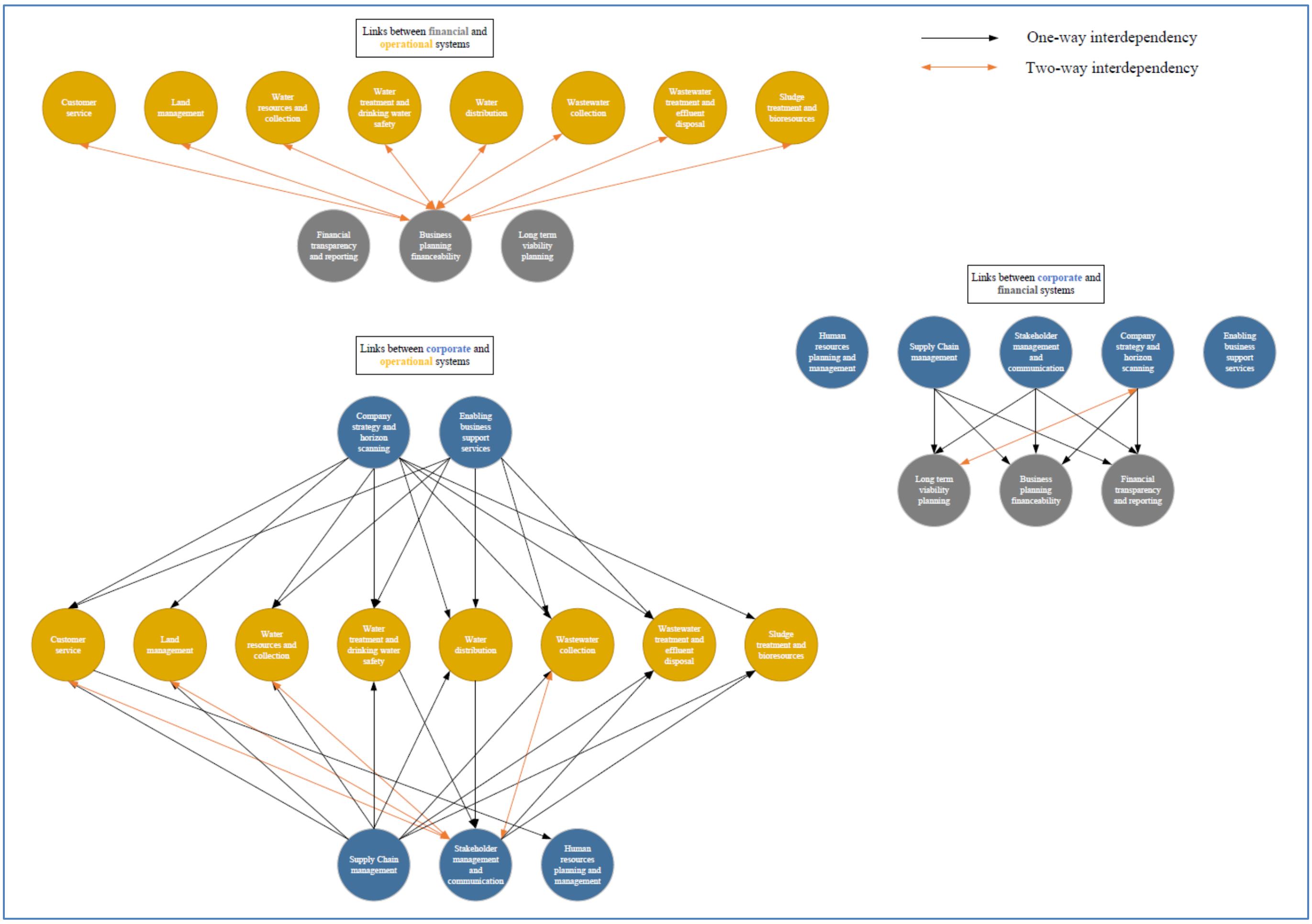


Figure. 5: Interdependencies of key Yorkshire Water resilience systems: showing strong interdependencies only.

Collection, Water Treatment & Drinking Water Safety, and Water Distribution; these are used to introduce each of these key areas later in the document.

Our approach to resilience will continue to evolve over time with awareness of the latest evidence and understanding, and in response to societal expectations. The cyclical nature of our business planning supports this ongoing evolution of approach to ensure our investment and operational activity is also based on latest evidence, best practice and potential innovation.

Following on from our work with Arup we have externally verified our approach to the best practice British Standard for Organisational Resilience (BS 65000), demonstrating our maturity and good governance. We are committed to maintaining this standard, and converting to the new parallel ISO resilience standard once it has matured. This will confirm our maintenance of a highly mature and robust approach, and will require our regular demonstration of continual improvement.

2.4 Drinking Water Safety Plan risks and long-term strategy

DWSP is a key tool in the maintenance of water quality within Yorkshire Water. For several years we have used the concept of "Future Risks" within our DWSPs, as we believe that the future focussed understanding of risk is essential to obtaining maximum benefit from their use in directing activity to where it best delivers benefit.
Our DWSPs and their underlying data are at the heart of the development of our plans. This approach results in the identification of specific hazards and risks that we consider have the potential to result in deterioration of drinking water quality or acceptability over a short, medium or long-term period.

Our drinking water safety planning process is a holistic and consistent approach to the assessment of hazards to water quality from catchment to tap and incorporates our Distribution Operation and Maintenance Strategy (DOMS). This approach is subject to our continual review process (table 2) which identifies intolerable risks. We define intolerable risks as those residual risks that are potentially harmful to human health and which cannot be mitigated through sustainable company operations. The reviews consider short, medium and long-term control measures to reflect the time it takes for mitigation to have an impact on the hazard in terms of risk reduction.

Table 2: Description of short, medium and long-term control measures.

Measure	Description
Short-term	Generally implemented as part of the routine operations for the Company. Examples would include changes to procedures, operating conditions and routine flushing activity. Control measures would not be expected to improve the mitigation of risk over a period exceeding 1 year.
Medium-term	Likely to be implemented and monitored over several years, generally within an AMP. Control measures are likely to involve more profound changes to the control of processes, catchment investigation and engagement, or systematic flushing.
Long-term	Likely to be implemented over one or more AMP. Usually driven by long-term trends of deterioration in raw water quality, by which a future risk can be inferred for the supply. Control measures would typically involve the building of new processes, the development of new sources and WTW, major trunk main refurbishment schemes, and catchment management. These control measures have differing degrees of uncertainty in terms of the speed of delivery, effectiveness in delivering the outcome and the time required for the control measure to reduce the impact of the hazard.

We have used those future risk trends to estimate when, if un-mitigated, raw water quality would be such as to result in the reduction in treatment works outputs or an unacceptable deterioration in treated water quality. This is consistent with the approach adopted as part of Water Resource Management Planning (WRMP) where we use the volumes which WTWs are capable of outputting, given the current raw water envelope, rather than their nameplate outputs. To address those raw water deterioration risks, catchment management remains our primary strategic approach and our first-choice intervention. By understanding the timescale to impact we can determine whether catchment management, additional treatment, or a combination of both, provide the most appropriate solution.

We have plans for significant further research in this area and on catchment remediation techniques during the latter years of AMP6, and into AMP7. We have included plans for significant surveys of raw water transmission assets to confirm they are fit for purpose for the future and do not present a threat to resilience.

2.5 Asset based review

We have reviewed the current age, condition and performance of our water production assets and identified where these require future enhancement such as more robust treatment, improved control, or run-to-waste facilities.

We have reviewed the condition of our trunk mains and have plans for future investigations, including the extension of automated conditioning techniques, along with targeted replacement or rehabilitation. We have reviewed the condition and location of our services reservoir assets, paying particular attention to the very large strategic assets approaching the end of their predicted asset lives, or where there are site constraints that would prevent a simple engineered solution.

We have reviewed our Water Network Strategy and have identified plans to improve the use of our flushing methodology as the short to medium term solution to customer acceptability, along with the development of new approaches to target the remediation or renewal of the network.

We see one of the greatest challenges for the future being the solution to the impact of lead on public health. We participated in the Water UK summit on the subject in late 2017, in the expectation that this would begin the development of a coordinated, multi-agency approach to resolving this risk. We are currently in the midst of a two-year study at the University of Huddersfield to understand in much more detail the nuances of interaction between lead pipe, bulk water chemistry and phosphate. There is also a need to gather more evidence on the conditions within properties which drive non-compliance.

Within AMP7 we have committed to ensuring that no Yorkshire schools are supplied by a lead pipe – this will require the cooperation of others within Local Authorities and other agencies. We see the greatest challenge for the future being the ability to remove all lead pipe and lead donors from potable water systems within properties, and ultimately the ability to cease phosphate dosing. The Water Industry, and Yorkshire Water as a part of it, has its part to play in this, but to be successful and efficient will require coherent support from Government, Public Health, Housing organisations, including the change of regulation and ownership, and cannot be simply focussed on the Water Industry.

2.6 Development of Strategic Principles to inform our future direction and Asset-based review

Our approach to developing our future direction grew out of a series of workshops which reviewed the world as we perceive it is likely to be in 2045, based on the evidence and trends we have today. It reviewed the needs of our customers, of which there will be a further million, and identified our place in responding to the pressures identified during this activity.

Table 3: Future pressures identified in Strategic Direction 2018 document.

Key factors included in our view to 2040	Measure	Now	AMP11 (2040)
Demand	Ml/d	1200-1650	1000-1450
Leakage	Ml/d	287	150
PCC	l/h/d	135	100
Water Quality	% passed	99.96	100
Population	Million	5	6
Asset Health: Unplanned shutdowns	No.	761	0
Asset Health: OFWAT outage	% non-availability	10%	0
Interruptions to supply (CML)	Mins	9.6	2
WTW incidents & events	Per annum	5	0
Customer experience contacts	No.	9000	1000
No. of unsupported customers (single supplies)			Zero service impact

We identified a number of key principles, which reflect the way we plan to achieve the outcomes set out in our Strategic Direction document and used these to derive performance and service statements for our assets.

Figure. 6: Key principles from the future strategy workshops

Over the next 25 years we plan to invest £2.8 billion to ensure we can continue to deliver water that meets the stringent standards required. The investment will be targeted at:

- Addressing deteriorating raw water quality from moorland, rivers and groundwater.
- Driving down complaints associated with discolouration and taste & odour.
- Managing and maintaining our WTWs and water network to secure and improve compliance with quality standards.

We are planning to increase our maintenance activity by 45% between 2020-2030 to maintain the long-term reliability and sustainability of assets and services, with a focus on ensuring compliance with water quality standards. We will continue to develop how we integrate the impacts of climate change in our planning and will review and update our plans at regular intervals to ensure that we always act on the latest available data.

2.7 Developing our strategy to mitigate future risk with our customers

Yorkshire Water is developing a long-term water strategy which focuses on water quality and acceptability as well as its' water resources. The PR19 submission to the DWI and the Draft WRMP were developed in accordance with the early years of this strategy. The strategy is fundamentally based on outcomes that were developed with customers, and derived from what they told us was important to them:

- We provide you with water that is clean and safe to drink
- We make sure that you always have enough water

These outcomes were developed with customers five years ago and over recent years, we have had nearly 19,000 customer conversations across a wide variety of formats. The conversations have helped us understand more about what is important to our customers now and in the future.

Our customers want us to stop failures in service from affecting their lives. For this reason, we need to ensure that our water supply system is resilient and sustainable, and can deliver both the quantity and quality requirements. We will take less from the environment and maximise use of the water that is abstracted. We will ensure we take action to tackle losses and the wasting of water in every way, and we will do this in a way that does not compromise water quality or acceptability, allowing us to improve our performance in this area.
We need to be mindful of future challenges and the impact they have on drinking water quality, acceptability and resources. The table below summaries the key future challenges we face and their potential impact on our water supplies.

Table 4: Key future challenges and impacts on water supply.

	Impacts on:		
	Quality	Acceptability	Quantity
Population growth			•
Growing economy			•
Climate change	•	•	•
Changing weather patterns	•	•	•
Environmental protection	•		•
Agriculture & land use	•	•	•
Asset deterioration	•	•	•

For each of our water sources and our distribution network, we have identified current and future impacts on quality and acceptability.

Table 5: Potential water quality and acceptability impacts on raw water (by water source); treatment and distribution.

Impact	Raw water			Treated Water		
	Ground	River	Reservoir	Treatment	Distribution	Customer
Saline intrusion	•			•		
Nitrate	•	•		•		
Pesticides	•	•	•	•		
Colour		•	•	•		
Asset failure	•			•	•	
Micro-organism	•	•	•	•	•	•
Pipe material					•	•
Tap material						•
Lead						•

3.0 Water Resources & Catchment management

3.1 Yorkshire Water's Water Resources

Approximately 45% of the water that we supply is from impounding reservoirs, 33% from rivers and 22% from groundwater abstractions. This varies from year to year depending on weather conditions. The Yorkshire Water region is bound in the west and north by the hills of the Pennines and the North York Moors respectively. The southern and eastern parts of the region are low lying. Annual average rainfall in the region is highest in areas of the Pennines, whilst low lying areas average less than half the volume of rainfall each year, with little seasonal variation.

Urban areas in the west and south are principally supplied from reservoirs in the Pennines. The Pennines and the valleys of the rivers Don, Aire, Wharfe, Calder, Nidd and Colne are as a proportion the largest resource in the region. We operate over 100 impounding reservoirs, and two major pumped storage reservoirs; the total storage capacity of all the impounding reservoirs is 160,410Ml. We have an agreement with Severn Trent Water to abstract up to 21,550Ml per year from the Derwent Valley reservoirs in Derbyshire. This water is used to supply part of South Yorkshire.

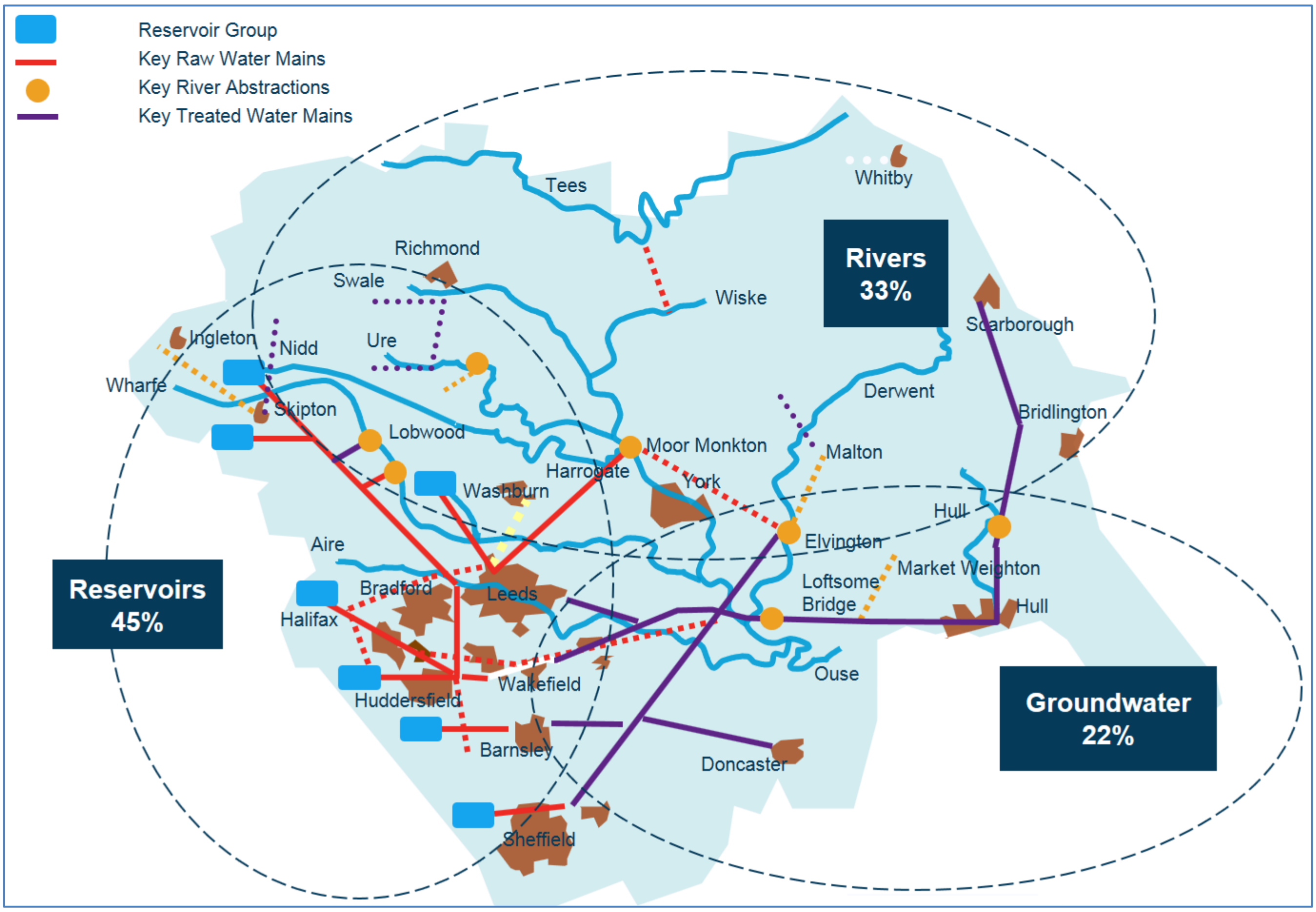


Figure. 7: Water resources in the Yorkshire region.

In the eastern and northern parts of the region, the major water sources are boreholes and river abstractions, chiefly from the rivers of the North York Moors and the Yorkshire Wolds. Most of these water resources are now connected by a grid network. This enables highly effective conjunctive use of different water resources, which mitigates risk and allows optimal planning, optimal source operation, and resilient sources of supply both in drought and during floods.

In the following section we identify the challenges we face across all our catchments and their location within the Yorkshire Region. The risks are diverse and vary according to source type and location.

3.2 Raw Water Risks to Drinking Water Quality

Many current and future risks to drinking water quality and acceptability relate to hazards that arise in the catchments from which we abstract. The graph to the right shows the proportion of our DWSP risks which are related to catchment hazards. In addition, many of these carry forward to treatment risks as we assess our ability to mitigate the impact of those risks.

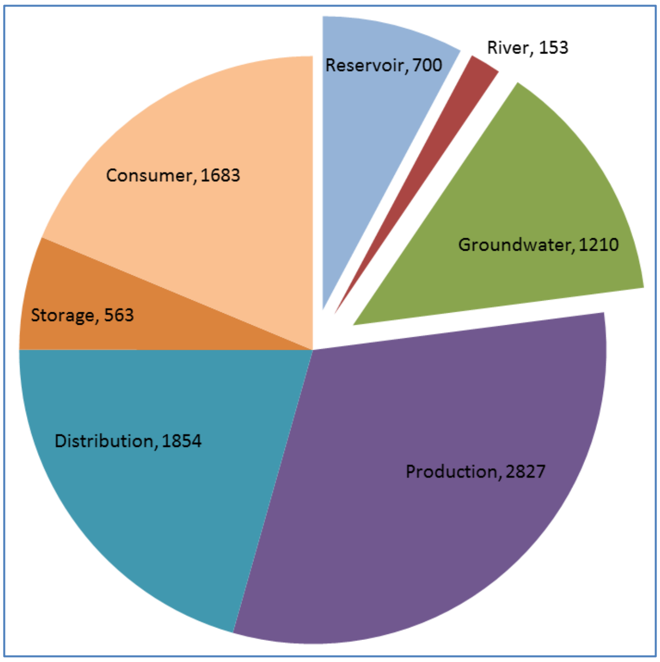
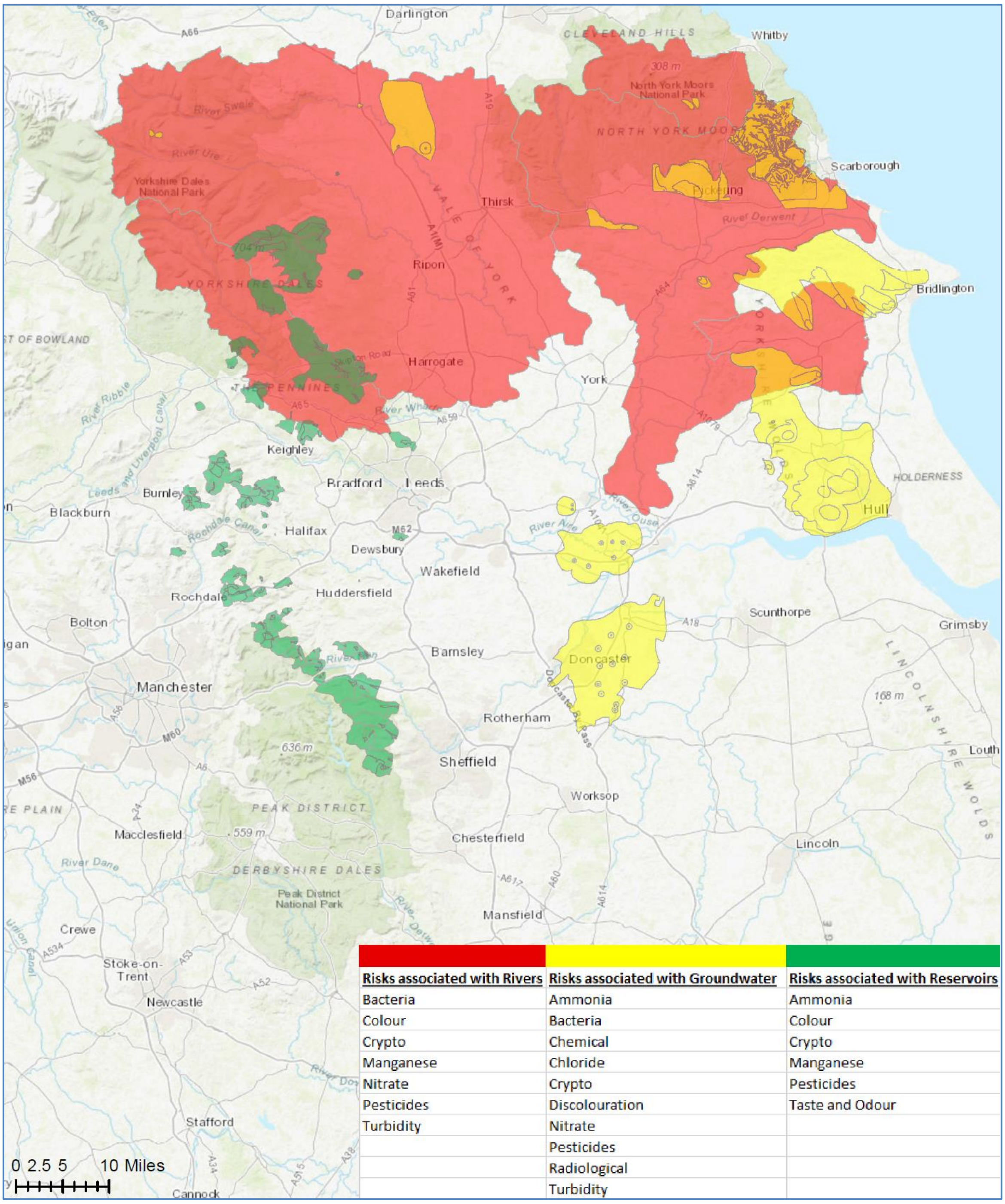


Figure. 8: The proportion of our DWSP risks which are related to catchment hazards.

In our DWSPs we observe significant risks to our customers that can be influenced by the weather and climate, from:

- Disinfection by-products (DBPs)- (particularly trihalomethanes)
- Cryptosporidium
- Pesticides (particularly metaldehyde)
- nitrate
- Other substances and organisms (eg taste & odour from algae).

In the following section we have mapped the location of hazards within our catchments as a means of aiding the understanding of where hazards arise and the extensive nature of their location.



Risks associated with Rivers	Risks associated with Groundwater	Risks associated with Reservoirs
Bacteria	Ammonia	Ammonia
Colour	Bacteria	Colour
Crypto	Chemical	Crypto
Manganese	Chloride	Manganese
Nitrate	Crypto	Pesticides
Pesticides	Discolouration	Taste and Odour
Turbidity	Nitrate	
	Pesticides	
	Radiological	
	Turbidity	

Figure. 9: An overview of the hazards arising in the catchments.

Figure 9 provides an overview of the hazards arising in the catchments we rely on, and indicates the significant proportion of the Yorkshire Region that requires catchment management activities to reduce risks to water quality. The image also highlights how a catchment can have many associated risks depending on the relevant abstractions in the area.

On average we obtain 45% of our raw water from the peat uplands, primarily focussed on the Eastern slopes of the Pennine chain. This resource is fundamental to our ability to produce water for the Region.

Figure 10 identifies the key risks associated with our upland impounding reservoirs used for drinking water supply. The majority are at risk from colour and manganese, with several also at risk from *Cryptosporidium* due to land use activities. In addition, there has been a rise in algal blooms at key sites and an increase in cultivated marginal land in the catchments, poses an increased risk of pesticides and nutrients usage and potential run-off.

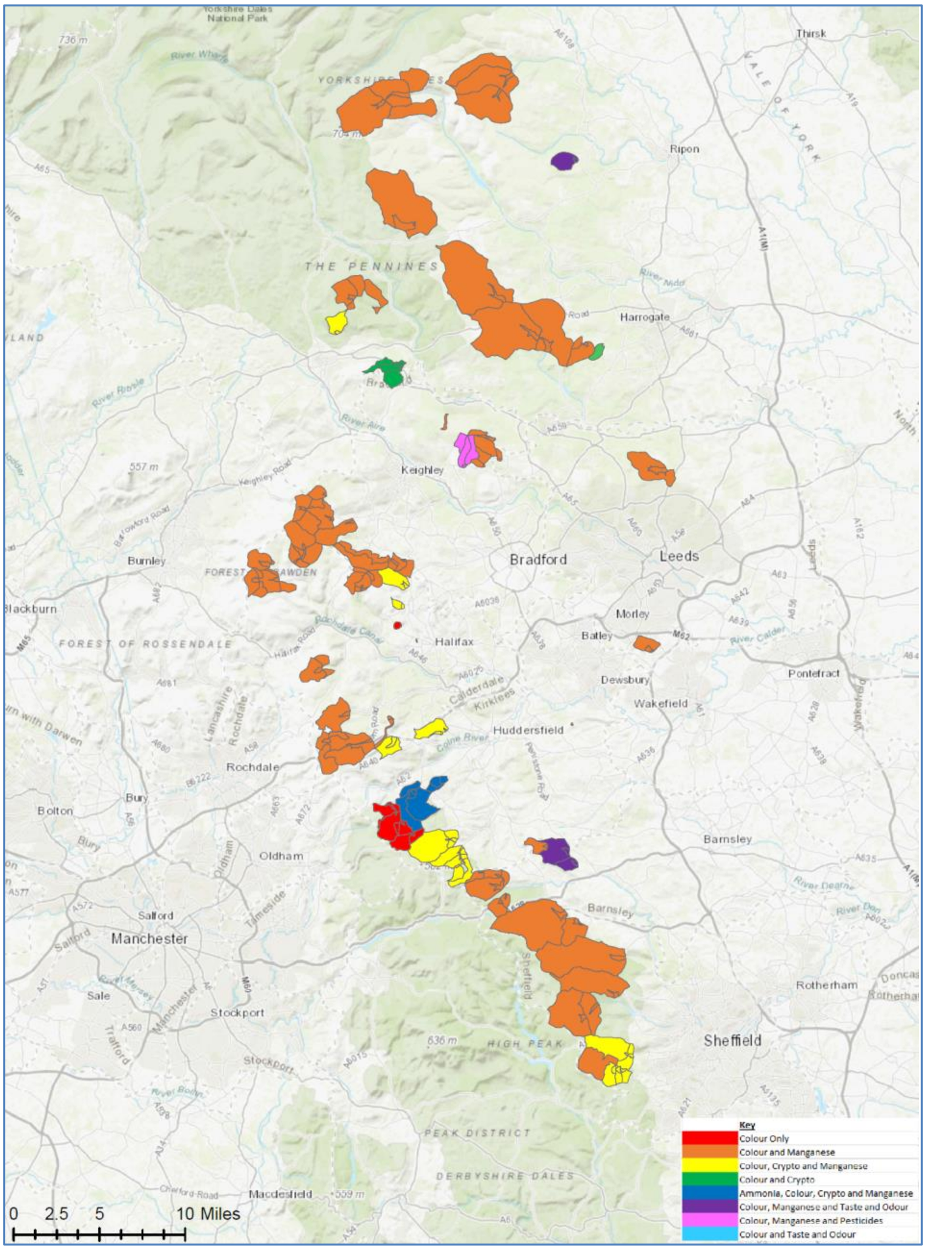


Figure. 10: Key risks associated with our upland impounding reservoirs used for drinking water supply.

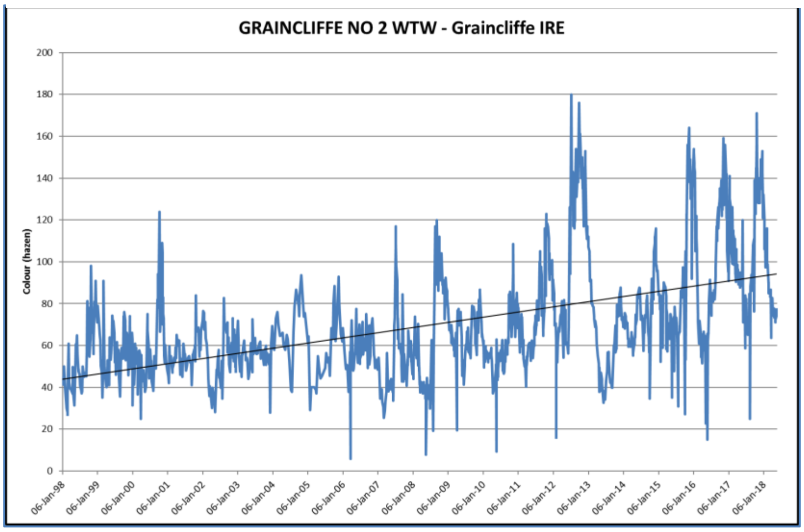


Figure. 11: Typical Upland raw water colour trend; 1998-2018.

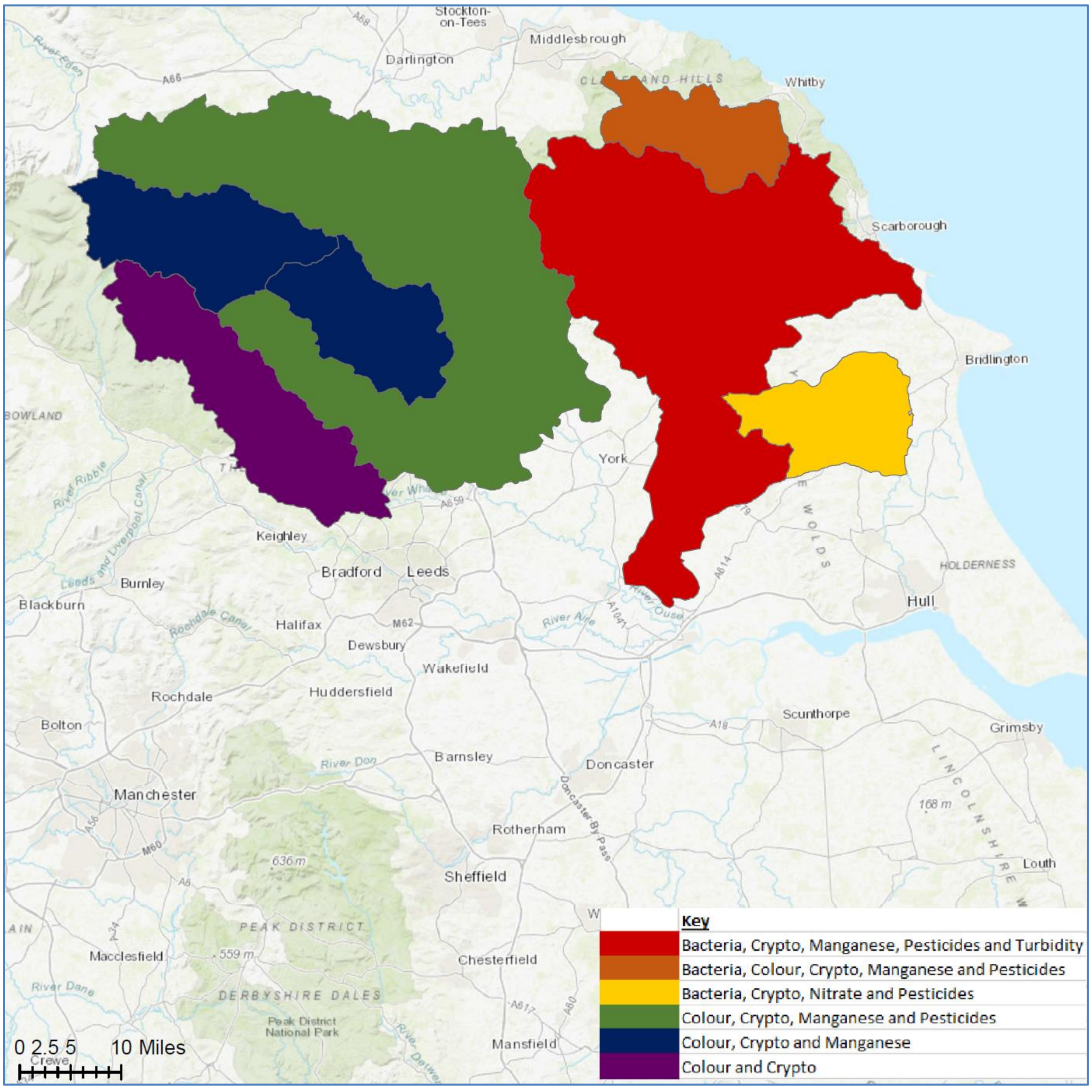


Figure. 12: Map highlighting the different risks associated with our river abstractions.

Figure 12 illustrates the different risks associated with our river abstractions, compared to the reservoir and groundwater catchments. These river catchments are highly influenced by agricultural activity and the majority of them are at risk from C*ryptosporidium* contamination and pesticide usage. The majority of the areas are targeted priority catchments by Natural England, such rivers include the Swale, Ure, Nidd, and upper Ouse (green, dark blue, and purple), and the Derwent (red). Increased sediment into the watercourses has associated risks such as nutrient loses, bacteria and pesticides, therefore, catchment management to reduce sediment loading on a river system can have multiple benefits, as well as improving land sustainability.

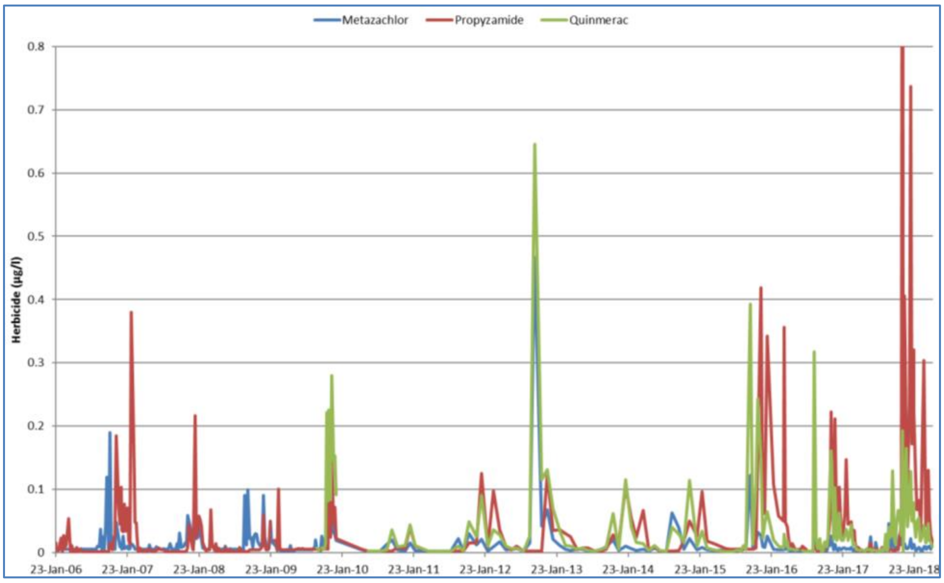


Figure. 13: Oil Seed Rape herbicides in River Derwent - 2006-2018.

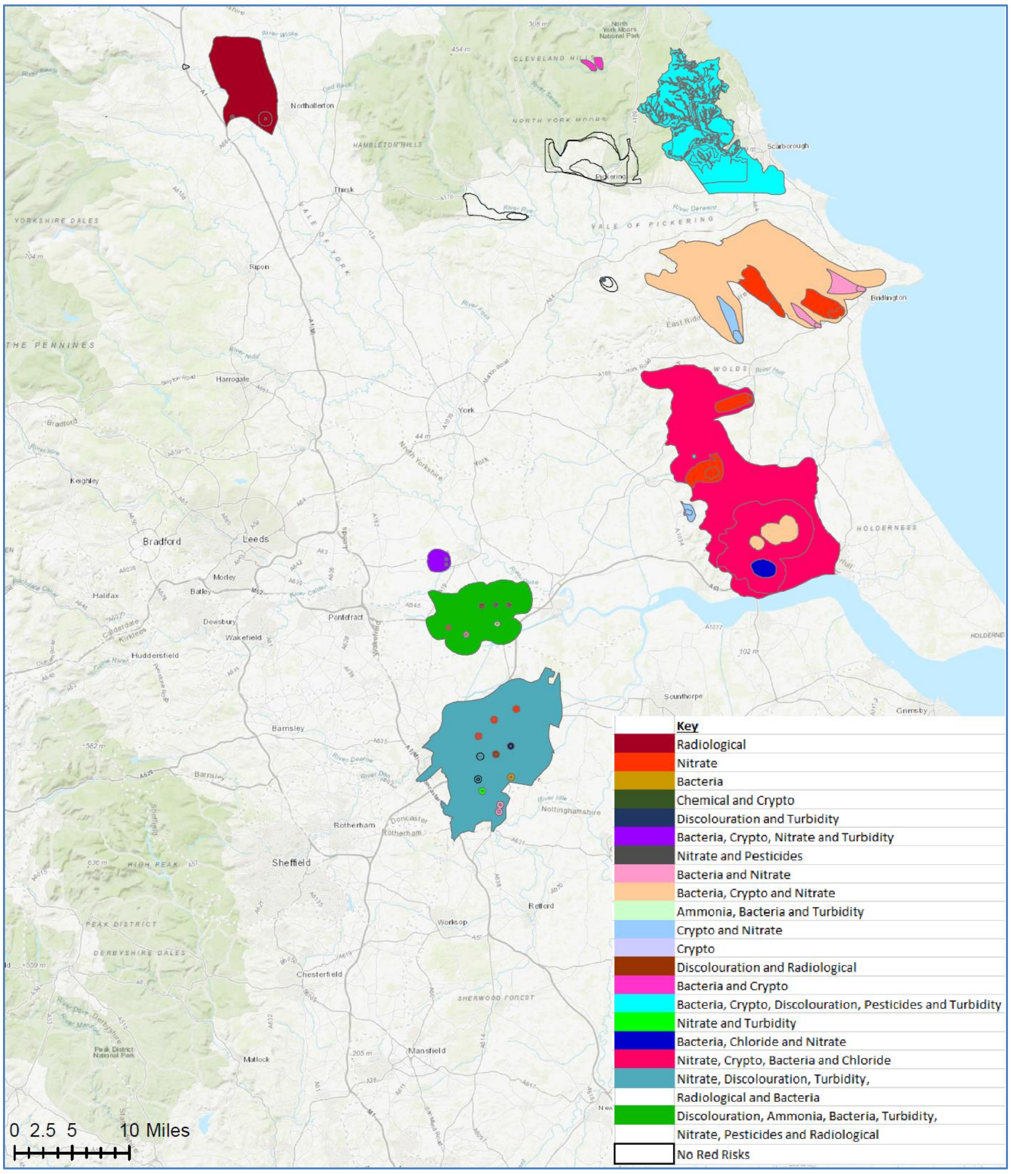


Figure. 14: key red risks associated with our groundwater abstractions.

The final map (figure 14) identifies the key risks associated with our groundwater abstractions. It identifies a clear difference in risks between the chalk and sandstone aquifers. The chalk boreholes tend to be at risk from nitrate, bacteria and *Cryptosporidium* contamination as a result of surface activities which have an influence on the level of risk to which the boreholes are exposed. Whereas, the sandstone aquifer is associated with risks such as turbidity, discolouration and uranium/α-activity, which are present due to the rock type rather than surface activity. There is however an exception associated with key borehole sites in the Selby and Doncaster areas, which are at risk from pesticide contamination, but the detections appear to be due to historic usage rather than present surface activity.

Yorkshire's resilient water resources position is fundamentally dependent on its' balanced portfolio of resources, these come under challenge under different weather (and climatic) conditions their overall risks to service and quality are balanced.

Of the range of risks identified above we consider the major considerations for the future to be related to colour/ Dissolved Organic Carbon (DOC) from our upland

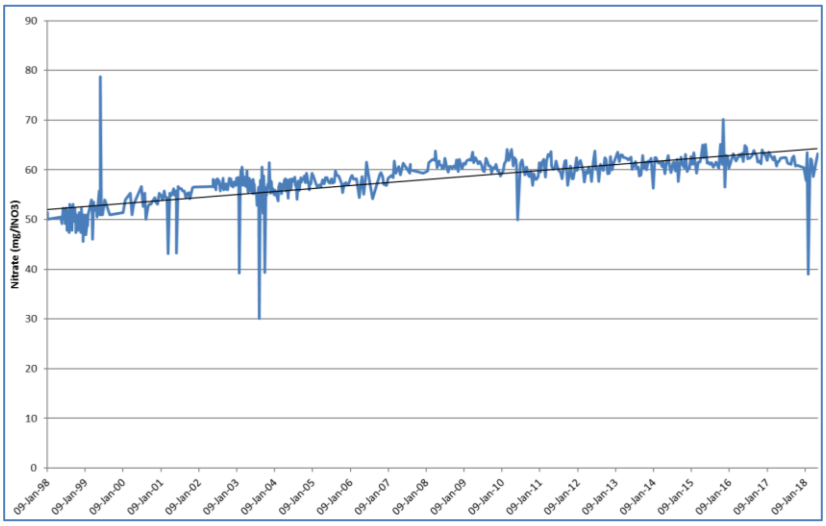


Figure. 15: Groundwater nitrate trend – East Yorkshire chalk aquifer – 1998-2018.

catchments, and nitrate impacts on our groundwater sources. We identify these over all other risks due to the time taken for mitigation activities to have an impact on the abstracted water quality.
We are also clear that the science is not yet completely understood and that this is an area where continued investment is required to finesse the evolution of interventions.

3.3 Resilience and Catchment Management

We have been undertaking significant peatland repair work for almost 20 years and this can be seen as developing the conditions required to repair the damage caused by decades of damage by drainage works, the changes to atmospheric conditions, land management, and climate change. However, significant activity remains if we are to restore these areas to well-functioning systems, rich in protective Sphagnum, which maximises their resistance to the effects of climate change etc.

As discussed in section 2.2, as part of their review of resilience, Arup studied the complex factors and relationships which describe the various impacts which the inherent properties of catchment land, and its management, can have on our business and water quality in particular.

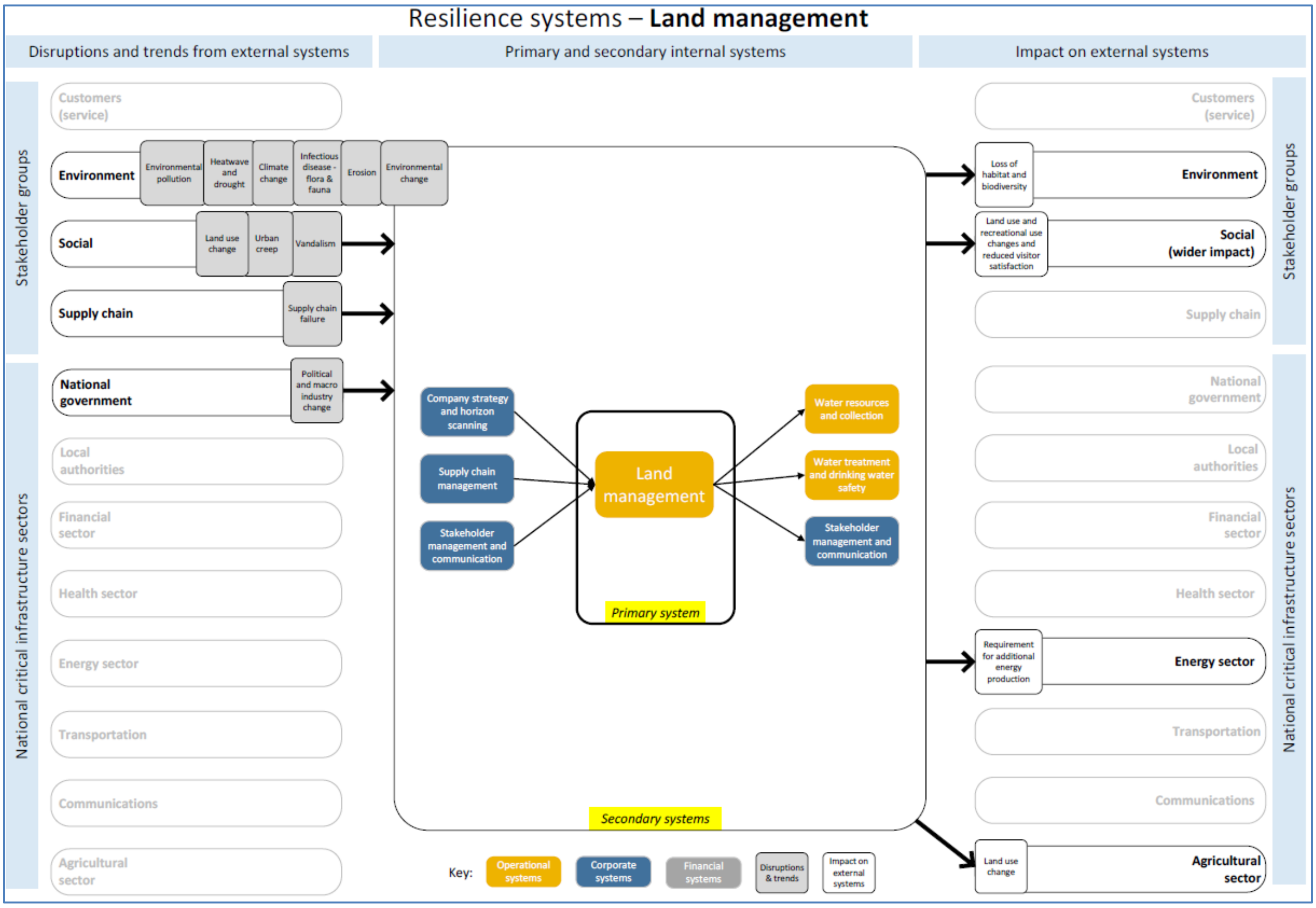


Figure. 16: This sub-system covers the land and property operations at YW, which manages over 70,000 acres of land across Yorkshire but is predominantly located on the eastern flanks of the Pennines and in Nidderdale. As well as managing YW's land, this system also covers the activities YW carry out with other land owners to protect the water environment (raw water quality).

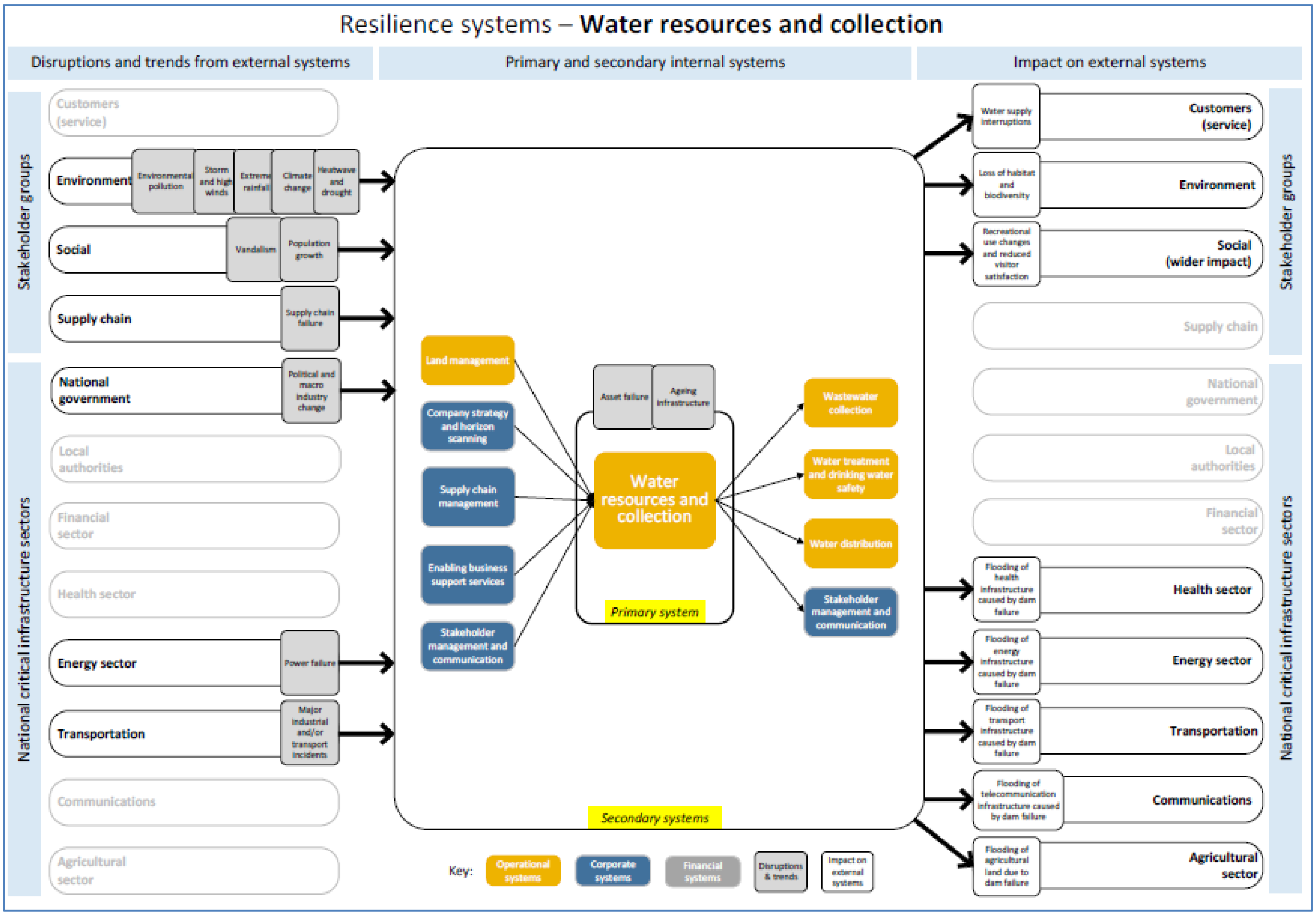


Figure. 17: Raw water transport: activities related to transporting the raw water or pre-treated water from the boundaries of the abstraction site/assets or pre-treatment assets through a distribution network to a treatment works, a raw water storage facility (balancing reservoirs/tanks), or to customers that require untreated or non-potable water (including third party water companies). It can also include blending of water from different sources. Raw water storage: activities related to the construction, operation and maintenance of raw water storage facilities.

- Climate change presents a number of risks to our ability to deliver clean, and safe drinking water. The key risk is from land management practices causing pollution of the water we abstract from the environment for treatment and supply. This is a complex area with multiple factors affecting land and how it is managed. Over-grazing, drainage, burning and other practices can leave bare peat and soil susceptible to erosion and therefore vulnerable to extreme weather. These practices also introduce air into the peat, allowing bacteria to break it down to form colour in water. Colour is removed through intense treatment processes to make it suitable for human supply. Healthy, vegetated peats and soils are more resilient to erosion, helping avoid water colour.
- The use of fertilisers and pesticides is likely to change as farming practices respond to climate change and other factors. For example, the amount of land being sown for Winter Oil Seed Rape has increased over recent years. This explains to some degree why we are seeing elevated levels of metaldehyde in the raw waters during Autumn along with other key active ingredients such as Quinmerac.

3.4 Research to inform our catchment activity

Yorkshire Water has had a long-term, and evolving approach to catchment management within the Region. This has been based on a knowledge and science based approach driven by our investment in research with universities and others. This is an area where evidence continues to evolve as the complex drivers, especially of DOC production in the uplands, become better understood. We have invested significant funding into fundamental and applied research associated with our requirements for catchment management.

Nitrate and other parameters present risks to a number of our groundwater sources. In the past, we have applied treatment solutions to ensure water quality compliance. In-line with our catchment based approach, we have been working with Arup to gather clear evidence based on source apportionment and water age to inform our understanding of the source of these problems and allow the best targeting of measures in a sustainable long-term response.

We have investigated the saline front in the Chalk aquifer under Hull to inform our risk understanding and response needs. The Chalk groundwater body has been assessed as 'poor' status under the Water Framework Directive (WFD) and is a problem for industrial and public water supply abstractions. Our source is outside the affected area but there is a risk the saline front could move inland if large abstraction is needed to maintain supplies during a drought. If our borehole supply becomes contaminated, we could lose this water source. Sampling over time will determine the dynamics of the saline intrusion and help to quantify the risk.

3.5 Catchment Management – Colour/DOC

Our catchment management programme covers a range of water quality parameters including colour, pesticides, nitrate and saline intrusion on reservoir, river and borehole sources. We are focusing our future moorland restoration activity on catchments where colour pollution is likely to overwhelm WTW capacity in the longer term. Our programme covers both implementation and investigations. Our activities will be delivered in partnership with a range of charities, landowners, regulatory agencies and other stakeholders where this is mutually beneficial.

We have been addressing the root causes of poor water quality for over fifteen years in order to provide an alternative to costly investment in extra water treatment capabilities. We have done this by investing in extensive monitoring, research and innovative land maintenance and restoration techniques. In addition, guided by the work of the Natural Capital Coalition, Forum for the Future, and the Crown Estate, we have defined six capitals which we will use to inform and support our Integrated Catchment Management approach.

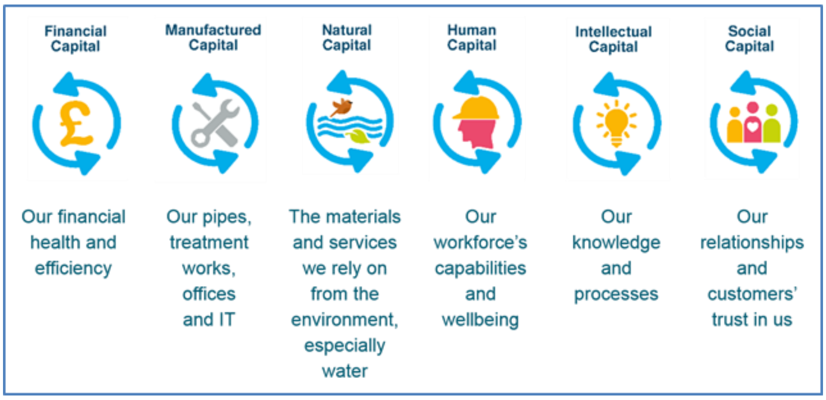


Figure. 18: Yorkshire Waters six capitals approach

This commitment to an evidence led approach demonstrates that Yorkshire Water is taking a lead to support multiple regional priorities, notably water quality and flood risk and seeking to go further by harmonising and embedding the six capitals, and the nine themes within its' "Beyond Nature" approach.

Through multi-agency partnerships we have delivered a range of industry-leading activities, including:

- Working with our tenants and Natural England on Keighley Moor to deliver catchment restoration in practice, forming the basis of an Ecosystem Services valuation, published by Natural England.
- Working with, and funding, Moors for the Future to improve 114 km^2 of blanket bog owned by us and 10 km^2 of land owned by the National Trust.
- Working with and funding the Yorkshire Peat Partnership to restore 10 km^2 of peat moorlands in Upper Nidderdale.
- Working with national experts such as Durham and Leeds Universities on an extensive programme of research.

Yorkshire Water has observed that opportunities for complementary outcomes and partnership working may be being missed due to a lack of holistic understanding of what is happening in the catchments. There is a need to understand the opportunities and synergies to then inform a robust implementation plan with recommendations for intervention. This commitment goes beyond our existing approaches, by quantifying and spatially mapping stocks and flows of all Six Capitals. When we can visualise the location and magnitude of the impacts of our (actual or proposed) activities, and those of other stakeholders in the catchments, we will be able to identify opportunities for partnership working, opportunities to optimise natural, social and human outcomes, and ways to increase the resilience of our catchments.

This review led us to develop an approach which looks at identifying all the enhancement and protection our catchments require, enables efficient delivery of interventions, and allows us to articulate our plans to others and bring external stakeholders into the delivery or maintenance of measures

We are planning to trial this approach to catchment investment within three drinking water catchments in response to a range of drivers and statutory obligations, for example the NERC Act 2006, Water Industry Act 1991 and Water Quality Regulations 2016. This will allow us to assess the potential for this approach to become the model used in future catchment management planning.

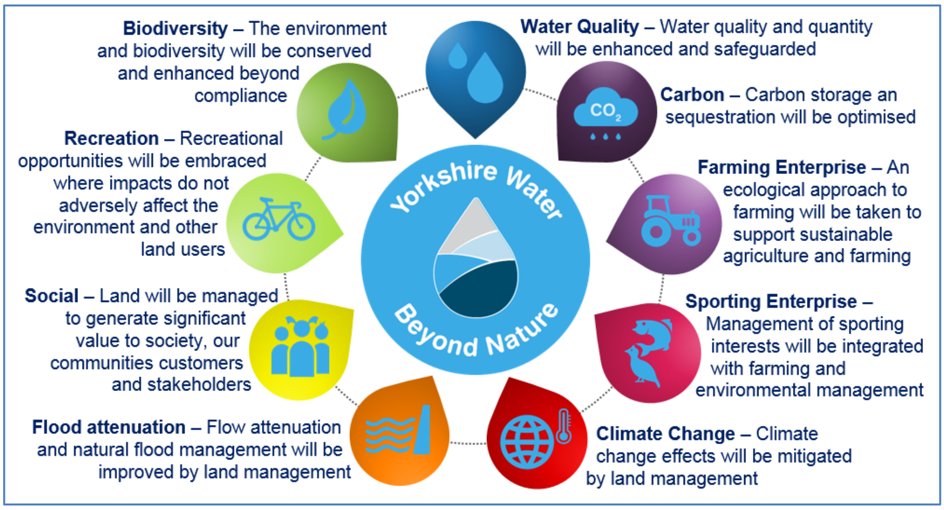


Figure. 19: Nine themes within the "Beyond Nature" approach.

In addition to meeting our statutory obligations, we will also be identifying ways to ‘add value’: choosing approaches which also enhance local ecosystem resilience, communities and economies. Over AMP6 we have evaluated the potential effectiveness and technical approach to catchment management for metaldehyde and nitrate. Our AMP7 plan is more ambitious than previous plans, as we seek to restore active peat formation to achieve functioning ecosystems. Through a collaborative approach we will continue to protect and improve Yorkshire’s water environment. In addition, we will gain a greater understanding of the potential opportunities remote sensing and aerial imaging can offer to assist in tracking the impact of activity and catchment understanding

Currently we have plans articulated to undertake the following activities:

- To improve raw drinking water quality by restoring peatlands.
- Peatland restoration to increase resilience.
- Optimisation of carbon conservation and sequestration by various components of work including sediment traps, grip blocking and reprofiling.
- To develop upon and improve the condition of our SSSI land holding.
- Develop and maintain a woodland management plan for all existing woodland and identify new planting opportunities.
- Increase awareness and understanding of the cultural and historical environment surrounding Nidderdale within the Chellow Heights Catchment through archaeological survey and conservation of historic environment sites.
- Biosecurity and the assessment of our risk and INNS appraisal of pathway investigations across the catchments.
- To improve the biodiversity and resilience of aquatic and riparian habitats and mitigate water quality failures.
- Recreation Reduce the impact on raw water services as result of recreation visitor (none tenant) use on raw water catchments through the provision of appropriate, well designed and safe visitor asset (car parks, toilet blocks etc), way marked routes, information provision, appropriate recreation activities, pollution controls.
- Reduce the impact on raw water as a result of erosion due to access to land. Provide new opportunities to access land, particularly for those with disabilities and underrepresented customer groups.
- Habitat management on Yorkshire Water land deemed high value for nature by Natural England mapping and Local Wildlife Status to help stop net S.41 habitat biodiversity loss.

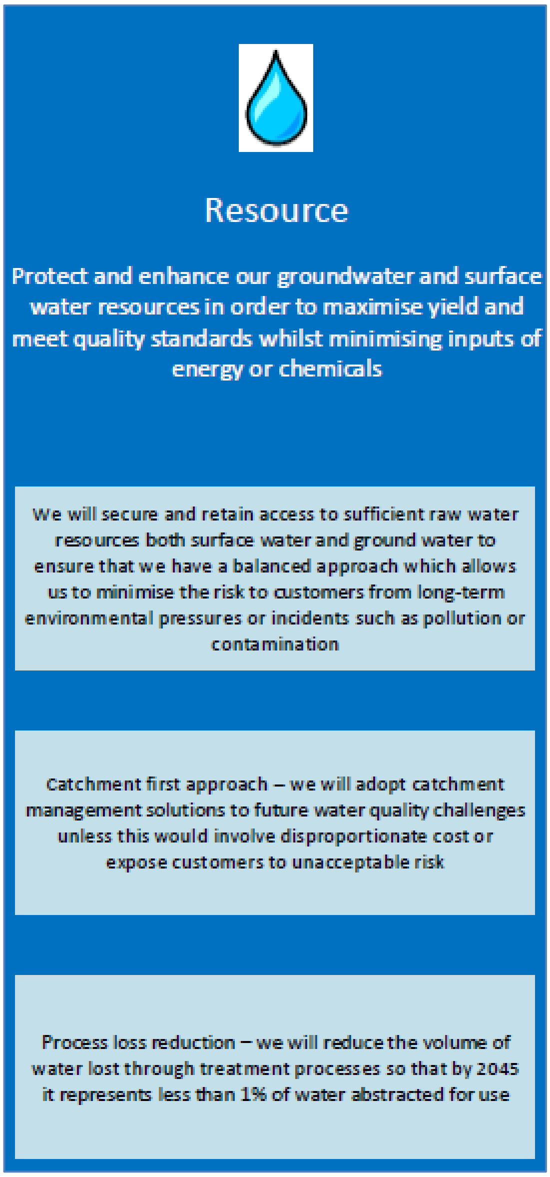


Figure. 20: Resource principles from the future strategy workshop.

- Promote nature tourism to capitalise on the high six capital values that the catchment brings.
- Facilitation of a wider partnership with farming and shooting tenants at landscape scale.

We will broaden and deepen our commitment to catchment management over the next five years and beyond. Our upland catchment management has currently focused on restoring past damage and preventing further damage taking place. We recognise the need to improve the upland catchments of Yorkshire, those we own, and those owned by others, as this is the most appropriate means of preventing further deterioration in raw water quality.

Figure. 21: Upland catchment: gully restoration.

This is especially critical as Yorkshire Water does not own much of the catchment areas from which its raw water is derived. It owns none of the catchment areas related to its groundwater resource, owns very little land within its river catchments – only those areas within upland catchments which feed down into river systems, and owns around 25% of the upland catchment areas. The map below indicates this and the proportions of land under Yorkshire Water ownership relative to the drinking water catchments. Even where we own the land it is often the case that shooting rights take precedence over our own, which can hamper progress in mitigating the deterioration of peatland.

3.6 Catchment Management - Nitrate Risk

During AMP6 we have undertaken a significant research project, undertaken by Arup, which has considered the age and residence time of the nitrate in groundwater to help inform effective response plans. We have focused on groundwater that is abstracted from one representative source in the Chalk aquifer and one in the Sherwood Sandstone. Key areas reviewed include:

- The impact of climate change on crop growth and associated use of fertiliser/pesticide.
- Investigating and modelling the likely changes in cropping and how we as a water supplier might influence this to prevent adverse effects on groundwater from use of fertilisers and pesticides; or if appropriate, surface water.
- Hydrogeological investigation into sources of water to inform future land management.
- Building on existing work to improve understanding of how rainfall travels into the groundwater and ultimately reaches our water sources. Including tracer studies, source protection zone delineation and detailed geological mapping.

With a clearer understanding of the sources of nitrate we have begun engagement with farming in the relevant catchments working alongside Catchment Sensitive Farming and others such as the Rivers Trusts. The nitrate concentration in groundwater abstracted at a number of Yorkshire Water sites shows a rising trends and some regularly exceeds PCV for nitrate (Figure 22). The Environment Agency have designated a Safeguard Zone (SgZ) under the WFD for the site (Figure 23). The SgZ requires implementation of an action plan to reverse the upward nitrate trend and establish groundwater nitrate concentration below 50 mg NO_3/l (11.3 mg N/l). We currently have an action plan in place, and our plans build on the work already in progress. Failure to achieve reductions in nitrate are likely to mean continued failure of WFD obligations and risk of additional treatment investment to prevent deterioration in water supply quality.

Investigations in AMP6 have produced a robust system of catchment characterisation and recommendations for engaging land users. These investigations have shown the need to characterise each catchment so that the nitrate source, pathway and receptor are clear to land users, abstractors and the regulator. The information collected will be used to engage with land users and promote changes in land use so that nitrate input to groundwater is reduced. The methods for engagement are given in more detail in this scope. The potentially most effective land use changes are identified in a report produced as part of our National Environment Programme (NEP) investigations in AMP6.

Additional benefits accrue from the opportunity to work with land users and raise awareness of other problems. For example, the setup of communication channels can assist with reducing; nitrate contamination of surface water; pesticide contamination of surface and groundwater, and sediment loss to surface water.

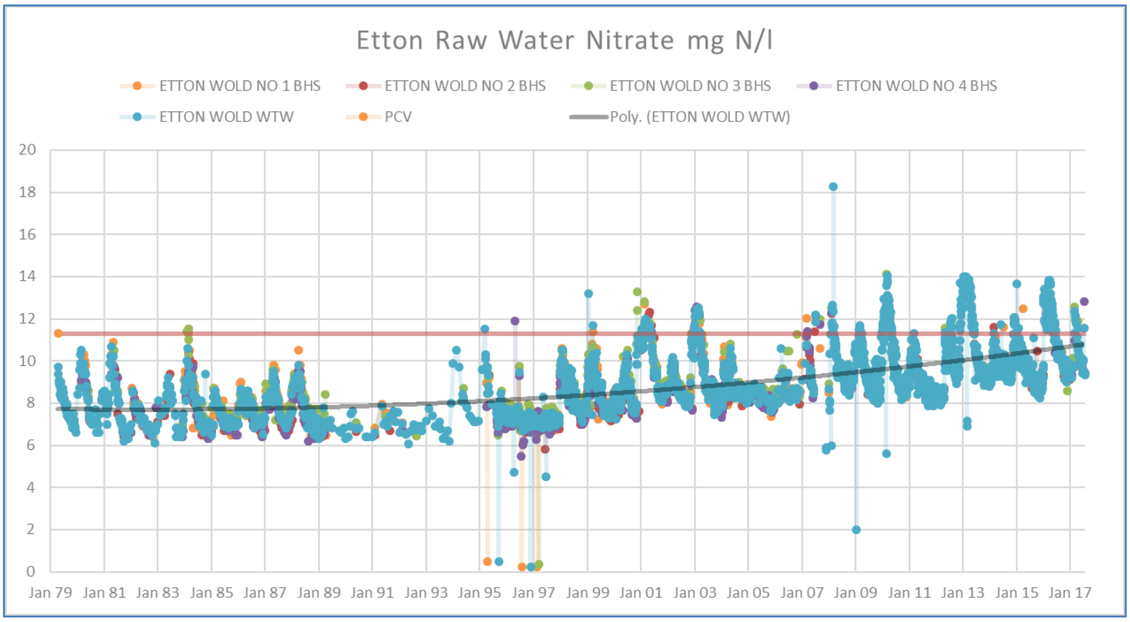


Figure. 22: Groundwater nitrate concentration at Etton abstraction from 1979 to 2017.

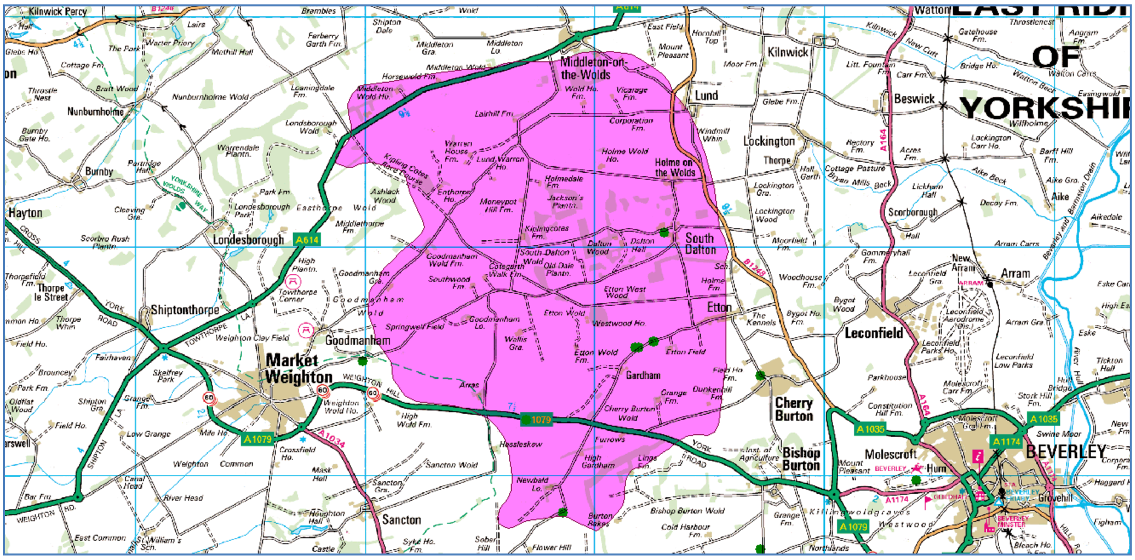


Figure. 23: Map showing Etton Safeguard Zone.

3.6.1 Catchment management scheme outline

We have identified the following stages as required to implement nitrate catchment management.

Catchment Characterisation

It is necessary to confirm the source of nitrate through a programme of groundwater sampling at company, private abstractions and observation wells. Samples will be analysed for:

- Total nitrate content,
- General water chemistry,
- Nitrogen and Oxygen stable isotope ratios to confirm nitrate source and
- Sulphur Hexafluoride to age the groundwater.

This allows the company to show evidence of the proportion of nitrate from different sources. The sources identified are agriculture, mains water leakage, sewer leakage, Sewage Treatment Works (STW) discharges to ground, aerial deposition, transport (from internal combustion engines). Groundwater aging is important to demonstrate the ongoing and recent effect of land use on groundwater quality. It is critical that this data is available for the catchment in order to effectively engage with land users. It also makes targeting and efficient application of measures possible.

Identification of flow paths is required to enable targeting of action with the SgZ. It is also needed to show land users how they impact on abstracted water quality. Flow path identification will be achieved through:

- Updates to understanding of geology and geological structure in bedrock and superficial deposits.
- Refined conceptual model of groundwater flow using revised geological information.
- As necessary production of a geological model.

Land user engagement

With the information from the catchment characterisation it is possible to open a dialogue with land users. The first task is to establish a working group with land owners. We will identify these people using spatial data resulting from the catchment characterisation above in collaboration with Natural England, the Environment Agency and Yorkshire Water. We will also commit to discuss formal look collaboration with Yorkshire Wildlife Trust; the Catchment Based Approach group and consultancy arrangements with Askham Bryan College. The college can provide anonymised summary information on actual activities on farms.

There will also be a general programme of engagement in the catchment and general area. This will be achieved by attending agricultural shows, events and meetings hosted both by Yorkshire Water and others. We will approach other organisations such as an agronomy service provider, some of whom we have worked with during AMP6, to attend farmer meetings. This has proved an effective method of engaging in local areas with farmers and their advisors.

Additional staff resources are needed to make the engagement possible. This will be done in collaboration with other catchment management schemes operated by the company. To undertake groundwater engagement two additional catchment officers are required. The company is also looking to recruit an additional hydrogeologist to support the enlarged WINEP programme. This includes work on water resources and water quality schemes. To support the work of the catchment officers we will use results of the characterisation work to generate material to reveal the 3D nature of the flow path from surface to abstraction.

Examples of the material we will produce are:

- Pictorial material showing flow paths and
- Where a geological model is present three-dimensional printed models showing geology, abstraction boreholes and flow paths.

There is also provision to support land users by trialling new equipment, outreach and communication with a range of aids showing the causes and association between nitrate at water supply boreholes and land use.

Monitoring and assessment of effectiveness

We will need to continue monitoring nitrate input to groundwater by sampling from abstractions and observation wells. This is necessary to demonstrate the effectiveness of the catchment management.
Monitoring is critical to show the results of the catchment management actions. If monitoring shows catchment management is not proving effective it will be necessary to plan for alternative measures to ensure the company meets its obligations for public water supply.

Summary of proposed actions:

- Characterise catchment – Improve geological, hydrogeological and hydrochemistry to enable focusing of resources and engagement with land users.
- Increase Staffing – recruit two full time catchment officers to work across all SgZs on nitrate catchment management.

- Engagement – set up local group with landowners to share the problem; make formal approach for collaborative working with existing catchment based groups; farm visits; attend meetings and events.
- Monitoring – water quality, land use, cropping, nitrate use.
- Review and refine measures.

It includes recommendations for engagement but the details for how this would be done are being worked up in these scopes.

3.7 Catchment Management - Pesticides

Metaldehyde remains a significant risk to compliance (CRI) in those supplies drawing water from the large lowland rivers of North and East Yorkshire. With a combined catchment area of around 5,000km^2, much of which is in use for arable production. The presence of metaldehyde is normally at the greatest during the Autumn period when winter cereals and Oil Seed Rape crops are being established, particularly following heavy rainfall events within the catchments.
Monitoring for this pesticide became well established in 2009 and the number of exceedances of the pesticide standard across the region since then are shown in the table below.

Table 6: Number of metaldehyde failures by year since 2009.

	2009	2010	2011	2012	2013	2014	2015	2016	2017
Total	18	1	6	33	2	15	9	8	11

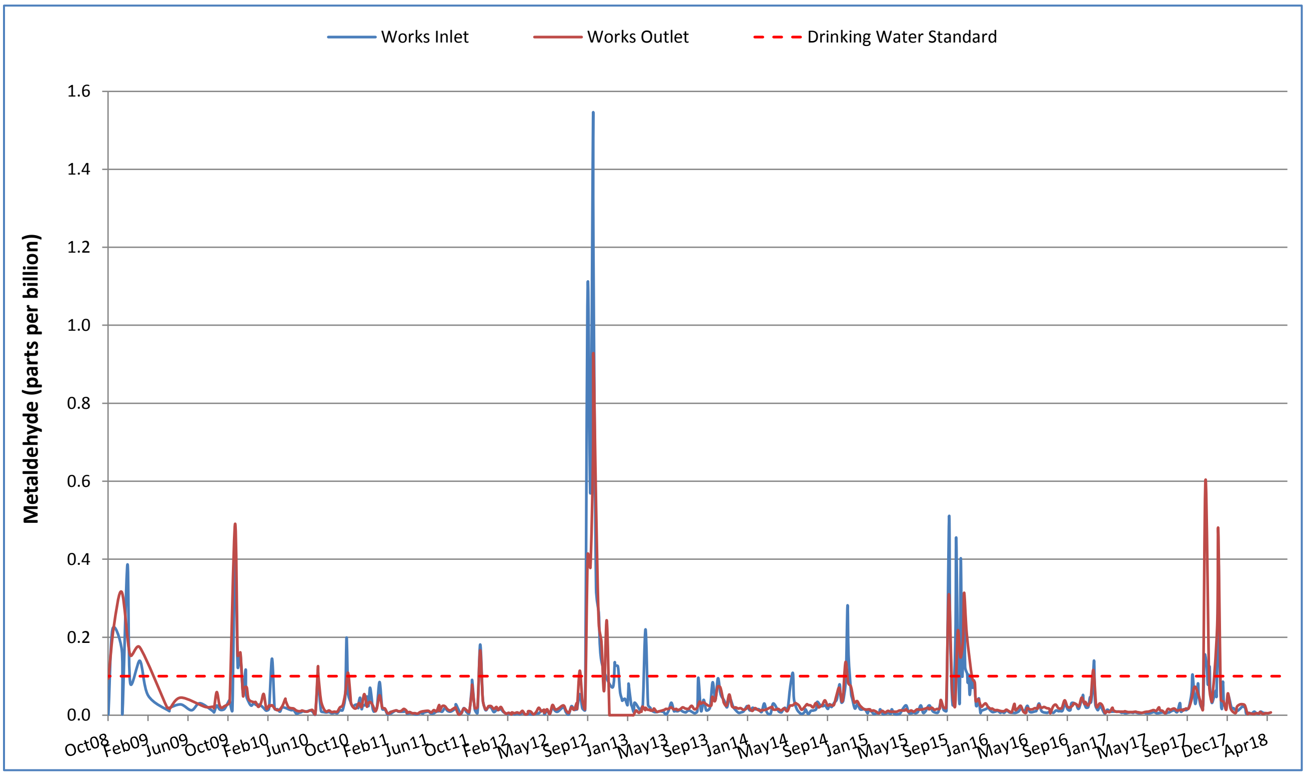


Figure. 24: Historic metaldehyde trends from the River Ouse – 2008-2018.

In March 2017 we provided reports to DWI on progress toward achieving compliance with the pesticide standard. In the reports, we discussed a payment for ecosystem services (PES) solution for a relatively small area in the north-east corner of the River Derwent catchment. This approach was readily adopted by the farming community and they are participating for a third year.

In addition, we have identified that abstractions are at risk from a range of herbicides associated in general with the growth of Oil Seed Rape or Blackgrass control. The challenge remains to manage metaldehyde risk in the large river catchments; We developed proposals within PR19 WINEP to scale-up the activities undertaken as investigations during AMP6 into new sub-catchments, and apply more intensive approaches in these and the existing sub-catchments identified as high risk. The activities associated with the reduction of metaldehyde risk are generally protective of risks from other active ingredients. We are concerned that if metaldehyde risk is controlled by restrictions of use we lose a key route to engagement with farming and regulatory support for many of the associated activities. We believe that it is in the long-term interests of raw water quality in general that these activities continue in support of a general pesticide risk reduction in raw waters, despite effective treatment being in place. This would address the WFD need to reduce the intensity of treatment required over time.

The key activities identified are:

- The continued employment of Catchment Sensitive Farming Officers through Natural England.
- The deployment of additional Catchment Officer resource by the Company.
- Development of more granular risk mapping and GIS tools to maximise impact of Catchment Officers.

- The development of better predictive techniques for the control room to allow better decision making around abstraction.
- Consideration of targeted PES schemes.
- Consideration of soil health advice to minimise use of chemical control products in general and metaldehyde in particular.
- Identifying ways of driving best practice farming activities from the early adopters into the catchments
- Working with the supply chain for arable products to promote metaldehyde free approaches.
- Developing an innovative system for the “loan” of equipment which brings significant risk reduction into catchments as a means of driving the penetration of new techniques into farming.
- More sustainable links with other catchment stakeholders such as the Rivers Trust and Yorkshire Wildlife Trust.

In future AMPs we foresee, our catchment management programme covering a range of risks to water quality including:

- Colour arising from peat degradation
- Nitrate
- Pesticides
- Saline intrusion
- Nutrients – to minimise algal growth

3.8 Impact of Land Ownership on our ability to act

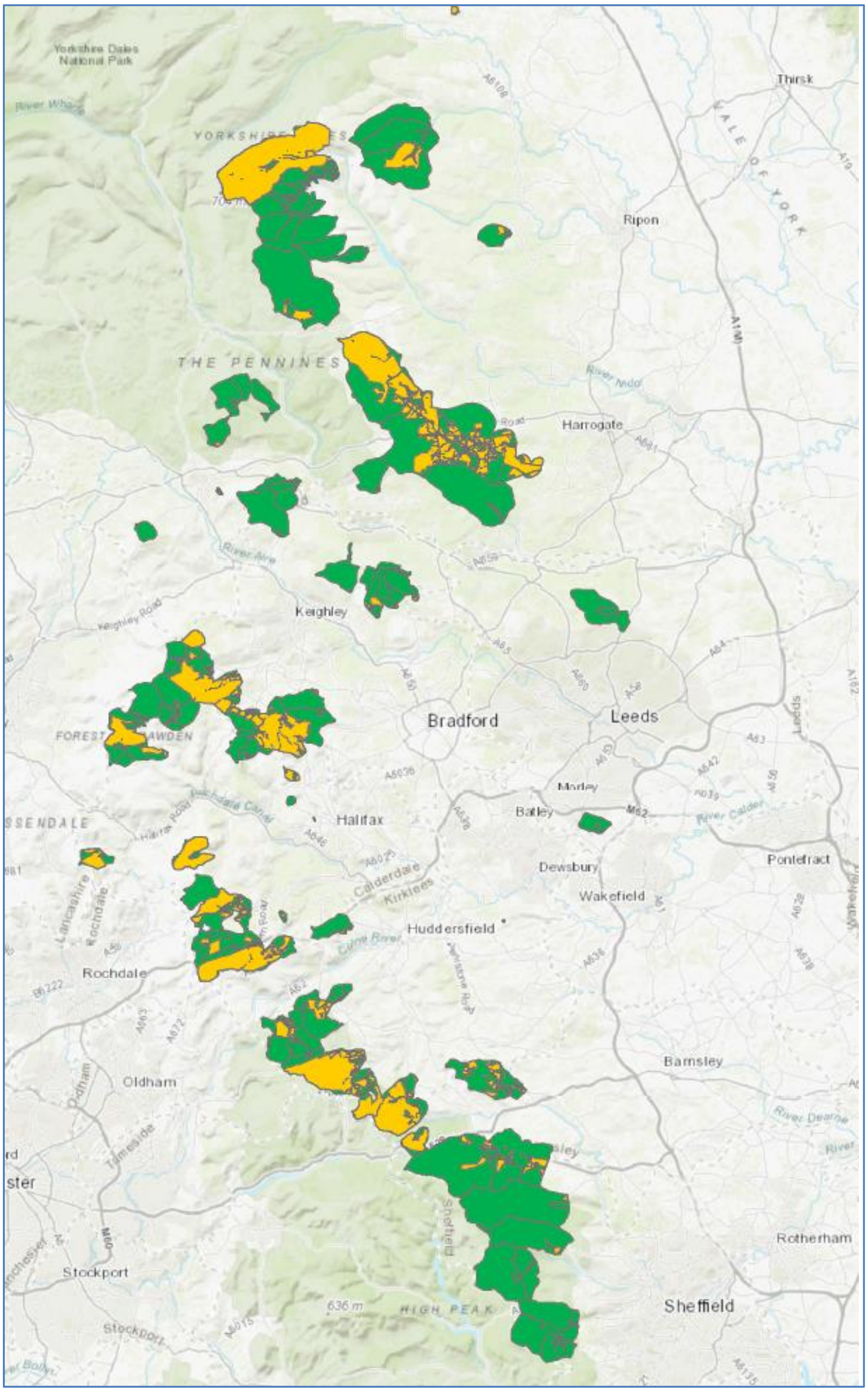


Figure. 25: Yorkshire Water Land Ownership (Yellow) - upland catchments (Green).

A key area of debate is around the need for multiple interventions on peatlands to secure conditions which protect water quality for the long-term. The activity undertaken in this and the previous AMPs can be viewed as repairing the hydrology of the catchment. For catchment management to be a long-term solution, there is a need for further phases of restoration of a functioning bog community, dominated by *Sphagnum* moss.

Our catchment management programme covers a range of specific water quality parameters including colour, pesticides, nitrate and saline intrusion on reservoir, river and borehole sources. It covers both implementation and investigations. The upland management schemes for colour will deliver a wide range of additional benefits to our customers and stakeholders, including flood risk attenuation, carbon mitigation and biodiversity. The programme will also contribute to resilience to climate change, which is a current risk identified under our Climate Change Adaptation Reporting requirement. We consider that our catchment programme is consistent with specific guidance, and has support for the approach, from Defra, the Environment Agency, Natural England and the DWI.

We have recently commissioned Leeds University to undertake additional research in support of our peatland management activity; this will provide us with evidence in the areas of:

- Evaluation of catchment restoration at the landscape scale
- A review of the success of various Sphagnum inoculation techniques and intensities; and
- An investigation into the processing of DOC which occurs in pools, streams and storage within catchments and raw water transmission.

Table 7: AMP7 expenditure on catchment management (subject to completion of PR19 processes).

AMP7 - Water Resources price control: WINEP Programme	Value
Catchment Management – colour & DOC	£ 12,096,384
Catchment Resilience & Biodiversity	£ 25,583,605
Groundwater – nitrate & pesticides	£ 6,603,573
Total	**£ 44,283,562**

Those will inform and better target our future activities in the restoration of peatland and protection of water quality which flows from them. Our aspiration is to significantly increase the level of expenditure in catchment management in the future, in our own right and in collaboration with other partnerships such as Yorkshire Peat Partnership (YPP) and Moors for the Future. We have indicated our desire to work with a wider range of catchment stakeholders in the future, and to influence a wider area of these catchments.

This can only be achieved if there is alignment of regulatory regimes, a shift in our ability to undertake or influence activity on non-owned catchments, the availability of support schemes not just for capital improvements, but maintenance too.

3.9 Water Resources and Catchment Management Summary

A key principle in our AMP7 planning is a "catchment first" approach. Our aim was to eliminate the need for future investment due to raw water deterioration by undertaking catchment remediation in sufficient time. Our current view is that this is unlikely to be achieved until AMP8, primarily due to the uncertainty around catchment management interventions to reduce colour risk, and external constraints on our ability to act. We currently predict that trends for nitrate can be managed primarily by catchment management, or in a couple of situations by additional blending or new low-nitrate boreholes. We have some concerns about changes to the farming activities on marginal land in some of our reservoir catchments. These have the potential to introduce new hazards into the catchment (e.g. nutrients and pesticides) which current treatment processes are not equipped to mitigate. Control of such changes are largely beyond our influence, in particular where we do not own the land in question. This is an area where coherent environmental policies are required to secure raw water quality for the long-term by supporting land management practices which do not compromise it.

We ensure our customers receive high quality drinking water despite deteriorating raw water quality through our twin-track approach of catchment management, with additional treatment only deployed where there is evidence that this will be successful. However, catchment management can take 10 to 15 years for the activities to demonstrate a benefit. In the short-term, we also need to enhance our water treatment works (WTWs) capability, because the probability of failure presents an unacceptable risk to our customers. This twin-track approach is appropriate when considering future climate change because it balances the immediate need for absolute certainty in the quality of drinking water with the long-term goal for a flexible, low-carbon, sustainable solution.

- Catchment management for colour stabilisation is critical for securing the long-term resilience and quality of our upland sources – these are 45% of our resource, and failure to manage this successfully, will require Ion-exchange treatment on many sources by AMP11 - this would imply an investment in additional treatment in the order of £140m Capital Expenditure (CAPEX), with the potential for a similar continuing commitment in subsequent periods.
- Catchment management for nitrate reduction in groundwaters is the sustainable approach and can be delivered with minimal risk of the need for further treatment. It would be supportive of our catchment management approaches if farming rules and agricultural support are developed into a soil health centred approach which is coherent and integrated to manage all risks from agriculture.
- Pesticides in groundwater – we identify the potential need for intervention at some specific sources as these are not following agricultural trends – the investigations will be completed during the early years of AMP7.
- Metaldehyde – we have not proposed activity specifically targeted at this pesticide – however, we believe that much more could be achieved if the product continues in use, by adoptions of the range of soil health centred policies, supported by appropriate incentives.
- AMP7 – should be seen as last period of major treatment investment with a crossover to catchment management in AMP8 and beyond – this requires a supporting coordinated approach by all Regulators to deliver the environment which will facilitate this.

We have increased our level of investment in upland catchment management within the AMP7 WINEP; we have a strong track record of support to other stakeholders active in these areas. We have significant research underway which will facilitate wider and improved interventions in subsequent AMPs to repair and restore the upland catchments of Yorkshire. To be fully effective this will require significant changes in the current constraints on our ability to act in catchments where we are not the landowner, or where sporting rights take precedence over ours. Government have indicated a direction of travel which appears supportive, but it is not clear that this will support both the restoration activities and subsequent maintenance of catchment enhancements in an integrated way. Only by doing this will society maximise the gains from investment in these activities.

In the area of catchment management for nitrate & pesticide risk reduction, we have built the relationships within catchments which will allow us to deliver significant risk reduction in future AMPs. However, this is hampered by fragmented Government policies in blunt restrictions and similar on farming activities, and a focus on capital delivery of measures only, rather than maintenance of what is good. The Government 25-year Environment Strategy talks about a soil health centred approach which we support; however, the level of investment committed to support it is tiny compared to that which we are committing. We await with interest the proposals for farming support following our leaving of the European Union (EU); to maximise the support for risk reduction this needs to be centred on soil health and especially soil organic matter and with other measures in support of minimising inputs which are potential risks to water quality.

4.0 Treatment

We use our understanding of raw water risks as a means of understanding the capability of our water treatment works to deliver safe, compliant and acceptable water for our customers. Production risks are the single largest proportion of our inventory of risks as they manage not only the risks inherent to the treatment processes themselves, but also the degree to which we assess trends in raw water quality impacting on the future risk to compliance etc. This allows us to predict future dates when we believe additional treatment will be required which can act as a driver to undertake prior investment in catchment management.

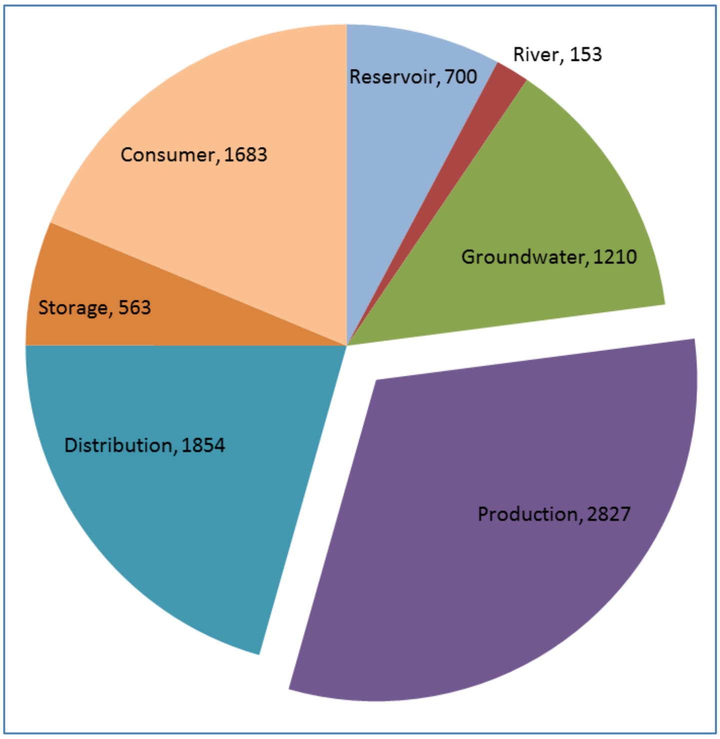


Figure. 26: Number of DWSP production risks.

As part of our recent development of WRMP we used this approach to assess the capability of our treatment works to deal with the current raw water envelope and how this relates to their design parameters. We used the capability of WTWs at their current and future predicted raw water envelopes to provide the output volumes used in the WRMP.

4.1 Treatment Resilience

Our ability to treat existing and predicted raw water quality and produce safe, acceptable drinking water has also been reviewed as a part of the Company's over-arching assessment of resilience. This has reviewed at high-level the factors with the potential to disrupt or perturb our ability to produce safe, acceptable drinking water.

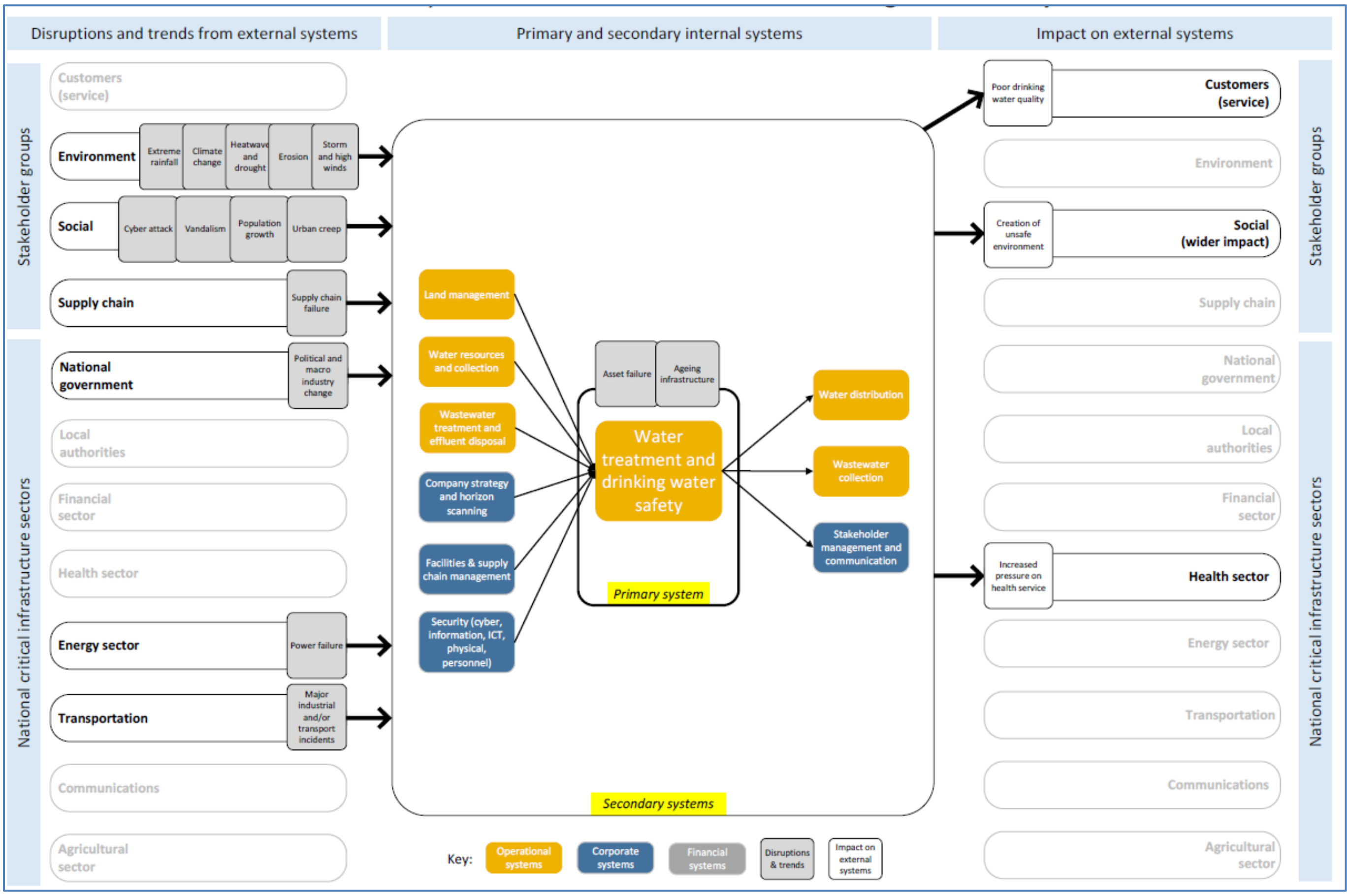


Figure. 27: Water treatment and Drinking Water Safety: High-level resilience systems - Receive raw or pre-treated (non-potable) water from raw water distribution network and undertake treatment processes. This sub-system also covers the asset management plan for this area of operations.

In the chapter on Catchments and Water Resources (3.0) we identified the key drivers and challenges perceived to current treatment strategies and assets. As part of this review we assessed all our current WTW capabilities against the current raw water quality – this was used as the basis for developing the plan for AMP7, and against the predicted raw water quality that is likely to exist at the end of AMP11 – used as the basis for this document. These predictions become increasingly uncertain but provide a useful basis on which to understand the future needs of our treatment processes, operators, and assets.

We have also assessed where treatment facilities will require significant capital activity to replace life-expired assets unable to continue to deliver service. A series of workshops helped us to identify where interventions were likely to be required over the 25 year horizon.

Many of Yorkshire Water's treatment assets were replaced in the 1990's and from a civil structural life perspective are likely to be able to continue to operate, subject to Mechanical and Electrical (M&E) and Instrumental, Control

Automation (ICA) replacements & enhancements for many AMPs to come. Our key concern relates to the on-going deterioration of peatland catchments for the reasons previously discussed with the DWI.

4.2 Water Treatment Works performance

As part of the supporting work for this document and our WRMP, we have undertaken a review of what our treatment works can deliver and what we require of them for the future, in terms of both quality and quantity. We have identified key actions which will allow us to deliver more reliable and resilient water production. This is focused on the key areas of maintenance and the prevention of and recovery from equipment failure to improve reliability, including:

- Good practice in maintaining assets, in particular for dosing systems and monitoring and control systems.
- Pro-active preventative replacement strategies and / or fail-safe back up facilities to reduce risk.
- Improved reliability and use of on-line monitoring systems to improve responsiveness.
- Developing a plan to retro-fit run to waste systems on all WTWs.

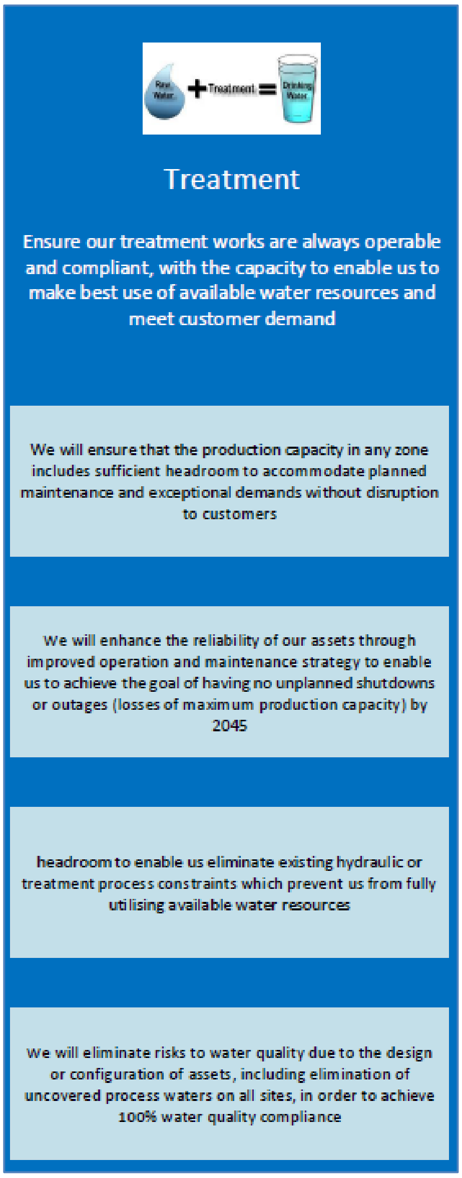


Figure. 28: Treatment principles identified by Long-term Strategy workshops

4.3 Potential future treatment investment requirements

Table 8: The potential future expenditure.

Intervention	AMP8	AMP9	AMP10	AMP11	AMP11+
I-Ex – colour/DBP	3 sites £45m	2 £30m	1 £15m	3 £50m	11 £165m
Run to Waste	8 £16m	3 £6m			
Manganese	1 £4m	2 £6m			
Algae	3 £9m				
nitrate	2 £6				
Pesticides	1 £6				

The potential future expenditure is dominated by the uncertainty around the ability to resolve colour/DOC levels from peat catchments – linked to DBP formation issues in treated water. We are keen to progress further with catchment management but in some cases, are constrained by other factors, especially on land we do not own (75%).

The predictions are based on the current regulatory framework for DBPs and make no allowance for the additional treatment that could be inferred by the current draft Drinking Water Directive – such as:

- Tighter DBP standards – eg a wider range of compounds (Trihalomethanes/ Haloacetic Acids (THM/HAAs)), or more stringent parametric values or interpretation of Regulation 26(2)a) – "Minimise".
- Endocrine Disrupting Compounds etc – future removal requirements.
- Viruses – more challenging disinfection requirements.

4.4 Future treatment technology

We recognise that the risks we face to water quality are constantly evolving, and that customer and regulatory expectations of our treatment processes increase over time. In response we have a strong record of investment in research into treatment technology, and this continues in support of our AMP7 plans and beyond.

- We are currently developing specific projects to look at alternative DOC removal technologies so that we have potential alternatives to MIEX given that we have significant investment planned in AMP7 and potential predicted schemes in AMP8.
- We are looking at "whole treatment train" alternatives for raw waters high in DOC and dissolved metals as we have a site for which we are planning a complete re-build in AMP7 alongside a quality enhancement scheme; and in the expectation that there may be other sites in the AMP 8-11 period.
- To facilitate a reduction in chlorine, use and customer reaction we will review the potential of emergent disinfection technologies such as LED-UV to provide effective disinfection in sensitive areas such as our National Parks.
- We will keep abreast of the state of the art in metaldehyde removal technology so that if required we can deploy it in the future, and understand its benefits to water treatment in general when existing ozone/ Granular Activated Carbon (GAC) systems become life expired.

4.5 Maintenance to deliver WTW resilience & Water Quality

As part of our operational improvement plans, an enhanced proactive maintenance strategy has been developed and is currently being trialled across 31 selected high-hazard operational sites for the remainder of AMP6. This is supported by the current recruitment of more Mechanical, Electrical, Instrumentation, Control and Automation (MEICA) technicians to deliver the activity on the assets.

This enhanced maintenance strategy is based on the principles of Reliability-Centred Maintenance (RCM) and is fully aligned with the Company's Systems, Applications & Products (SAP) Blueprint Programme. It has been designed to provide; accurate asset data, compliance with statutory requirements, together with condition-based assessment of performance, and repair/replacement information being generated through failure codes. This will enable whole life cost predictions based on service, spares and maintenance labour costs which will form an important asset health input to the DMF. This enhanced maintenance strategy is seen as key to improving our WTW outage performance commitment and reducing the risk of water quality impacting failures.

Timely completion of reactive maintenance, the availability of critical spares and more efficient ways of working will reduce the mean time to resolution and therefore minimise the impact of any outage events. Conditional monitoring of key assets will mean outage impacting events can be pre-empted and avoided, improving reliability and impacts due to breakdown.

This approach, delivered in parallel with the SAP refresh initiative offers the opportunity to change the overall approach to asset availability and reliability, reducing the risk of failure and the potential for loss of supply even further.

5.0 Networks, Storage & Customers

There are also water quality challenges to overcome in relation to our distribution network. The DWSP identifies a large number of risks relative to other stages in the source to tap journey – this is an artefact of the assessment of risks across each of the water supply zones of Yorkshire, rather than a reflection of actual risk.

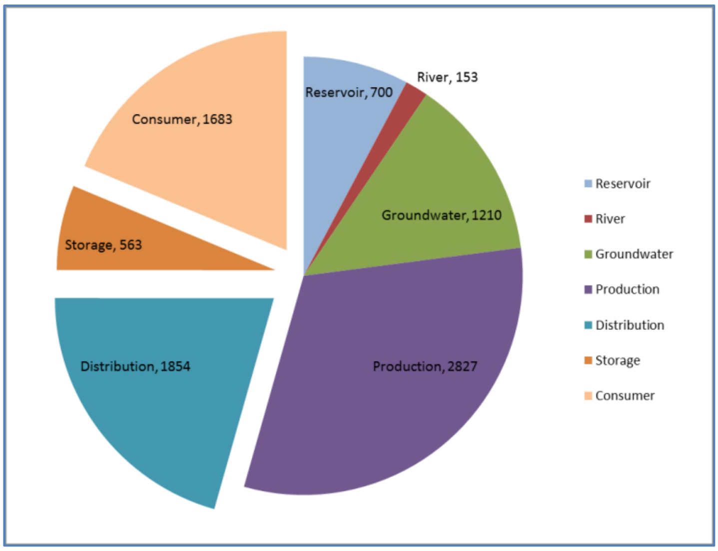


Figure. 29: The number of network and customer risks in DWSP

One of the main challenges we face is discoloured water caused by a build-up and release of material in the pipes. In addition, we are aware of the need for continuing focus on protecting the quality of water stored in service reservoirs. Whilst not usually a part of submissions to DWI, we are continuing to invest in the replacement and refurbishment of these assets, and identify where some strategic assets may require replacement in the context of a 25-year plan. Finally, there is the risk of exposure to lead which can result from the presence of lead pipes in some properties, mainly located between the water main and customers' taps.

5.1 Water Network Resilience

Our work with Arup identified the key high-level influences on our networks on which we rely to deliver service to customers and will inform our evolving Network Strategy, especially as we bring this together with the Water Supply System Resilience project facilitated by Stantec.

Between these two levels of resilience review, we identified some key principles as part of our asset-focussed workshops. These outcomes are generally focussed on the resilience of our own water supply systems, but also the part we may have to play in the national water resources and resilience work. As leaders in "Water Resources North" we potentially site between the water stressed South and East, and the relatively water abundant North & West, but currently in a balanced water resources position ourselves.

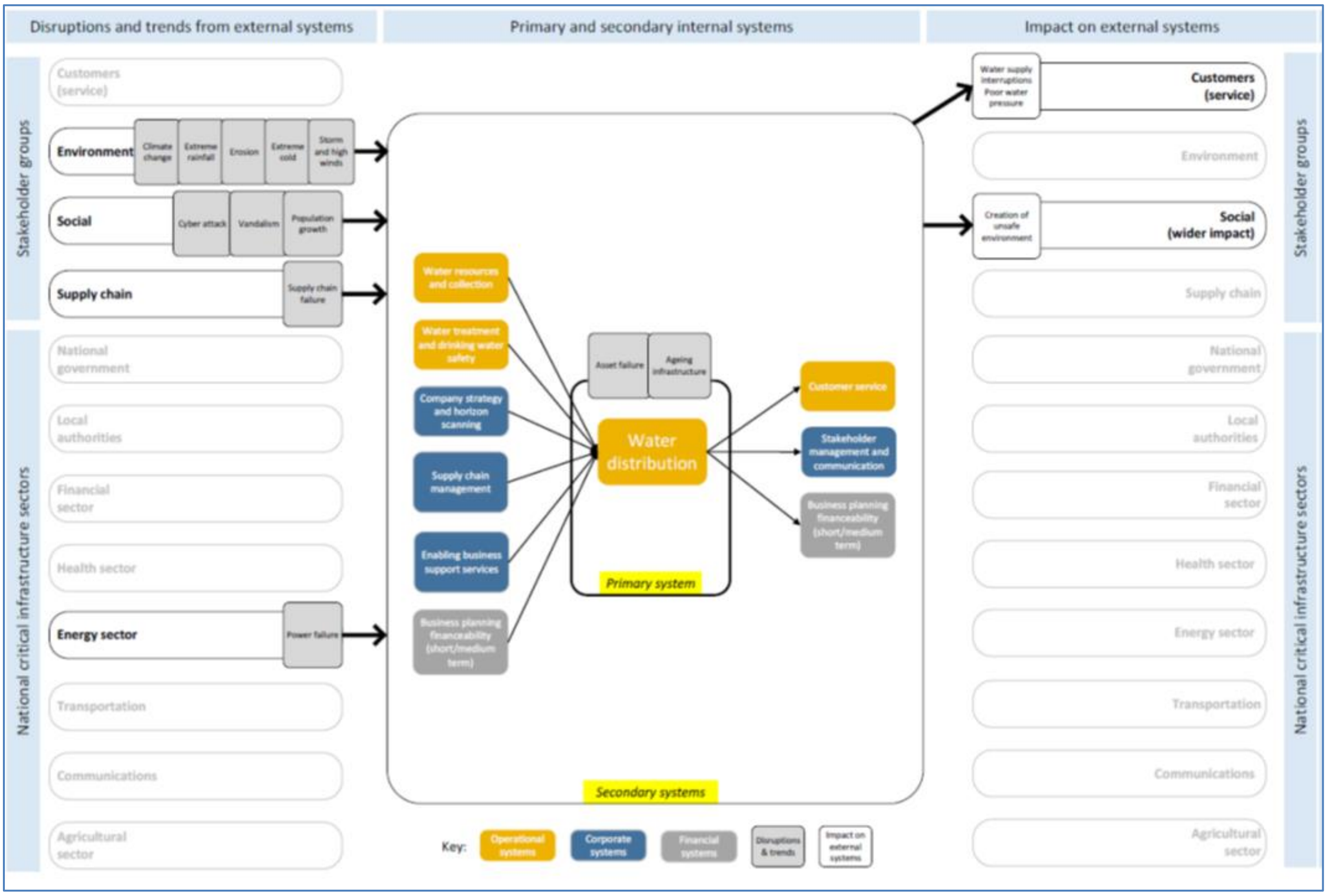


Figure. 30: Treated water distribution: activities related to transporting treated water from the treatment works to the customer including secondary disinfection and other chemical dosing. This includes all trunk and distribution network repair and maintenance activities, as well as activities associated with any new network development. Also included are the provision and maintenance of water towers and service reservoirs.

Our current Network Strategy focuses on how we deliver the five key water network outcomes that our customers expect, in the short, medium and longer term. These are:

- Asset reliability – our customers expect us to maintain our assets so that burst mains are reducing over time, service reservoirs are watertight and our pumping stations are reliable and efficient.
- Water quality – our customers expect a clean wholesome supply of water so passage through our water network has no detrimental effect on water quality.
- Interruptions to supply – we will be the frontier company for interruptions to supply.
- Leakage – will reduce to levels below that which current theory says are possible.
- Resilience – resilient asset planning will enable delivery of a resilient service.

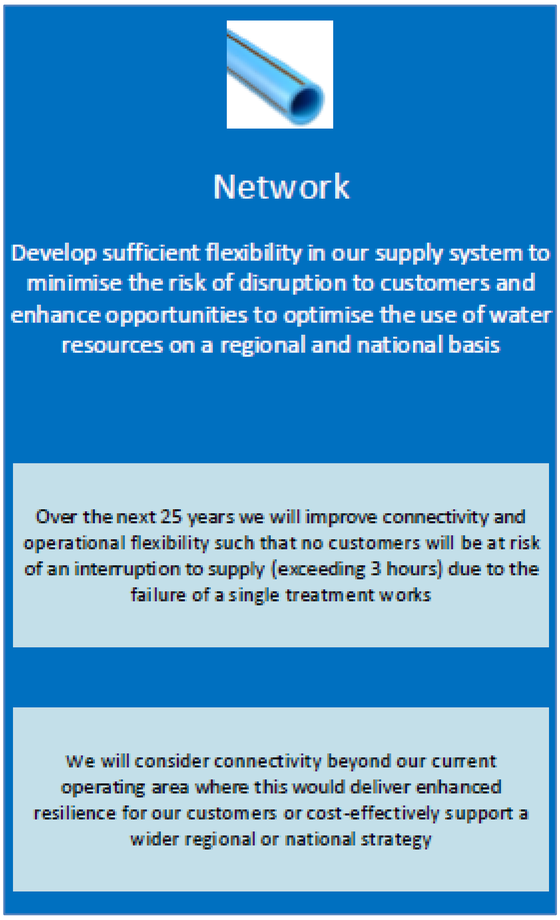


Figure. 31: Networks principles identified by Long-term Strategy workshops.

5.2 Ensuring Reliable Assets

Our customers expect us to maintain our asset base so that we can provide exceptional levels of service efficiently. They accept that assets will fail but expect us to manage the frequency of failure and mitigate the impact of failure. We aim to reduce burst mains by 10% each AMP, to eliminate both leakage and ingress from service reservoirs, to maintain pumping stations so that 98% of pumps are operable and to start to manage service pipes as an asset.

5.3 Network Maintenance

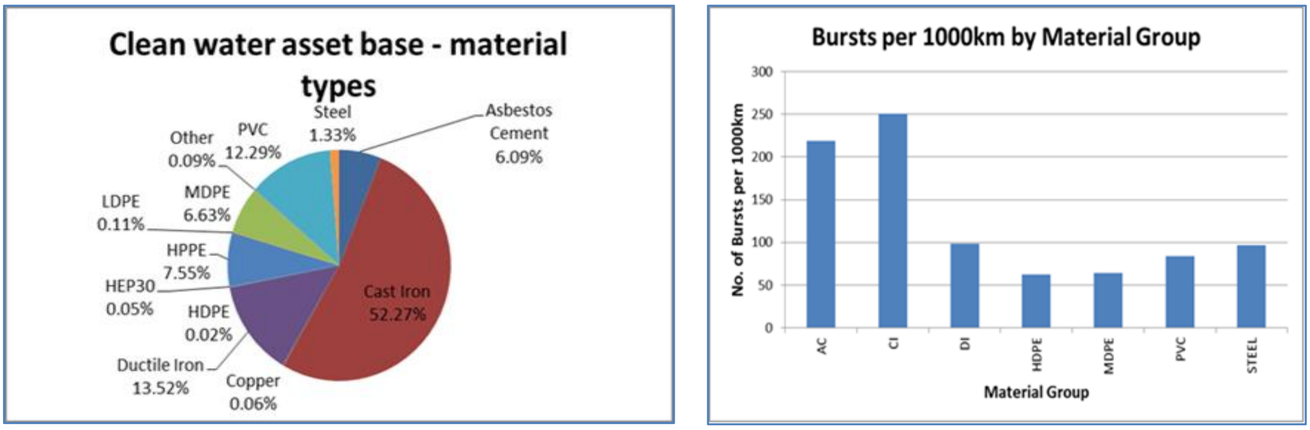


Figure. 32: Network maintenance data, comparing burst rates with different materials of construction.

Trunk Mains

We have historically invested very little on our trunk mains, despite these being strategic assets where the consequence of failure is significant in terms of cost and service. We recognise this and are planning a holistic asset management approach to reduce trunk main bursts by monitoring our trunk mains for transients and implementing a programme of proactive trunk main asset condition assessment which will cover 10% of our trunk mains every year. This will inform how we target renewing or structural lining of 0.5% of this network each year (ie 21.5km).

Distribution Network

Our current strategy of calm networks training for all operatives supported by mains renewal or structural lining of 1.5% per AMP is just sufficient to maintain the current burst frequency ie to combat deterioration in asset performance. Over the next 25 years we expect to reduce our current burst frequency by over 40% as a means of reducing our impact on customer service.

We have analysed the cause of historic burst mains by interpreting the feedback data we have available and found them to be:

- Ground movement – 47%
- Corrosion – 15%
- Pressure – 14%
- Fittings failure – 19%
- Other – 4%

However, the measures referred to above are insufficient over the long term to achieve our targeted reduction in burst frequency. We must increase our targeted distribution mains renewal or structural lining (decided on a scheme by scheme basis) programme to around 0.5% per year (ie 137.5km) and ensure it is targeted at preventing corrosion or ground movement related bursts. We will undertake research on the optimum pH and the impact of changing water sources on the rate of internal pipe corrosion. We are undertaking investigations on the rate of de-alkalisation of Asbestos Cement (AC) mains as a means to understand clearly their expected residual life and allow their replacement to be appropriately timed and prioritised in our asset replacement planning.

Figure. 33: Networks site maintenance site photo.

5.4 Distribution Network – Acceptability (turbidity, iron and manganese)

The levels of turbidity, iron and manganese leaving water treatment works have reduced significantly over the last 20 years due to investment in additional treatment stages and tighter operational practices. In addition, we have undertaken significant mains rehabilitation activity to drive down the levels of metals non-compliance and customer contacts. This has had a significant impact on the number of contacts received, and delivered improvements to water quality, but required high levels of investment over multiple AMPs. Following the end of this strategic programme, progress continued, but at a slower pace.

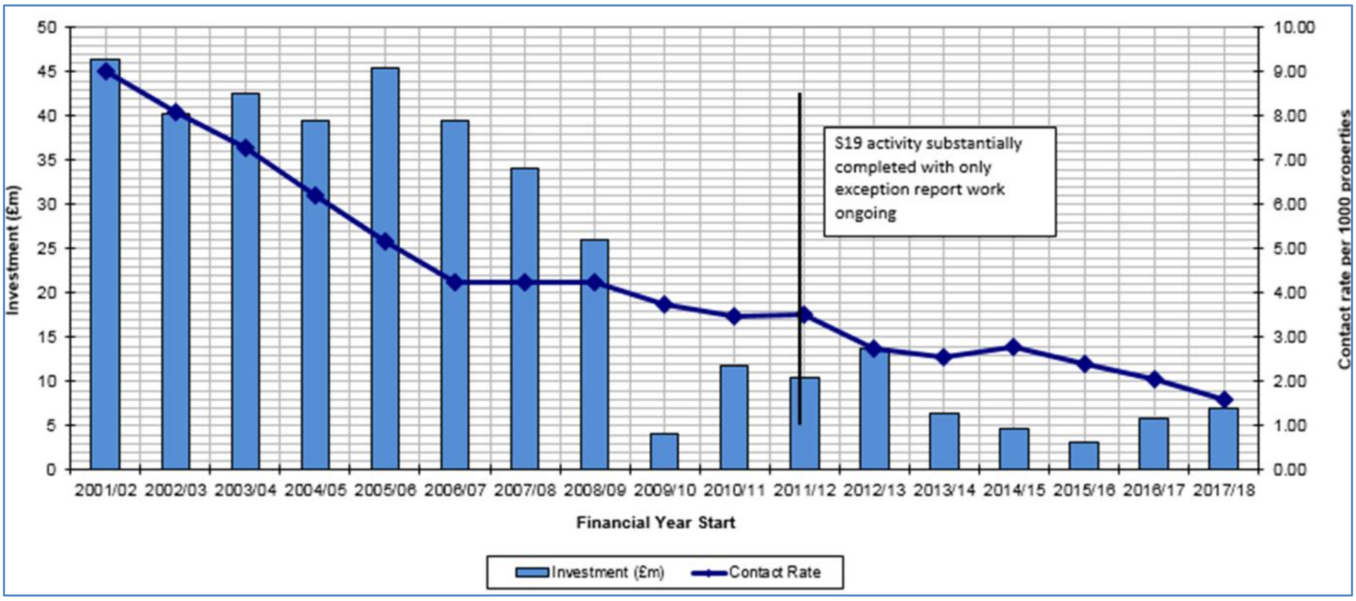


Figure. 34: Chart illustrating network maintenance investment and decreasing contact rate since AMP3.

Within AMP6 we have carried out an intensive systematic District Metered Area (DMA) flushing programme, which is delivering benefits to customers and compliance at a quicker pace again. However, we recognise that there are still some pockets of historic sediment remaining in our trunk mains that pose a high risk if disturbed.

Figure. 35: Networks flushing data gathering.

We will review the feasibility of trunk mains conditioning for sediment removal for all trunk mains during AMP7 with the intention of automating this where possible and where conditioning is not feasible investigate options for installation of cross connections, valves, re-zones, etc to enable this or include the trunk main in our renewal or lining programme for AMP8. This will form the basis for the on-going maintenance and enhancement of the performance of our network assets.

Our use of Work Authorisation Notes Database (WAND) for all valve operations to assess risk and our targeted DMA flushing programme and will continue, but will use a sediment depth model and regeneration rate to prioritise flushing and mains renewal or lining based on whole life cost rather than customer contacts. We will continue to support ongoing research at Sheffield University through the Prevention of Discolouration in Distribution Systems (PODDS) project, which will help us understand the potential truth of a recent theory regarding discolouration seeding being caused by low levels of manganese leaving treatment works, so we can target investment appropriately. Additional monitoring is required so we can respond and notify customers of events, initially in AMP7 with the installation of water quality (turbidity and chlorine) monitors at DMA inlets, but during AMP8 with the incorporation of these water quality monitors into our smart meter network.

Figure. 36: Networks flushing showing flow and quality monitoring on standpipe.

5.5 Distribution network – acceptability (taste and odour)

One of the key areas of water acceptability and one that we receive contacts from customers is taste and odour. This has three primary sources:

- Raw water (for example, algal content).
- Chlorine and chlorine reacting with compounds in the treated water.
- Interaction between plumbing and materials within the customer's property (usually plastic fittings, such as the tap) and chlorine and water characteristics (for example, bromide).

We have an active programme of chlorine optimisation, focused on our secondary dosing units and managed by a dedicated team of technicians. The aim being to maintain stable low levels of chlorine throughout the network. In some cases, the complaints are not directly related to chlorine itself but to its interaction with plastic fittings within the home. In some areas where water chemistry makes such occurrences more likely (eg high bromide groundwaters), we condition the water using cholramination to mitigate this issue. We are considering where we can extend the coverage of this approach during AMP7 and beyond, without constraining the flexibility of the supply system.

5.6 Reduction in risk of microbial contamination at Service Reservoirs

Our highest risk of compromising bacterial quality is at service reservoirs (SR). To maintain asset reliability, we have a long-term programme of service reservoir re-builds to maintain stable asset condition.

Figure. 37: SR emptied for inspection and cleaning.

Over the past few AMP periods this programme has focussed on:

- Rebuilding relatively few, smaller assets.
- Installing full roof membranes and drainage improvements.
- Strategic review large tanks / strategic storage / and their fit to water supply system resilience.

This is supported by improvements to enabling works so that all assets can be taken out for inspection and maintenance.

We have a robust programme of asset inspections which is dynamic, based on asset construction type and asset condition at the previous inspection. We operate a range of inspection frequencies from a minimum of 6 months to a maximum of 5 years. Most inspections are undertaken by draining the asset and allowing our engineers to enter the water space, usually in the context of a roof flood test; however, we sometimes use submersible technology to undertake inspections where required.

Our reducing leakage levels mean we will need to review service reservoir turnover time with winter and summer profiles. We plan to install more real-time monitoring in AMP7 to ensure we can maintain stable chlorine and turbidity levels on outlet of SRs with a view to linking to live hydraulic models in AMP9, following our smart metering programme in AMP8.

We will prevent ingress on the inlet or outlets to service reservoirs by reviewing hydraulic gradients and undertaking transient monitoring as part of our trunk main reliability programme. This will be supported by an on-site survey for all air valves on SR inlet/outlet mains to ensure free draining chambers.

5.7 Strategic storage review

In addition to the "routine" reviews of SR condition referred to above we have undertaken a further study of key strategic assets, based on their size, or other characteristics that change the perception of asset risk.

This review included a mixture of clear water tanks and strategic service reservoirs as the former also

Figure. 38: Service Reservoir roof membrane installation.

serve a storage function. Our review included those tanks covered under the Reservoir Safety regime and used for potable water storage; this did not identify any additional concerns about structural stability of assets.

Table 9: Strategic potable water storage tanks and indicative interventions, timescales & costs.

Timing	AMP8	AMP9	AMP10	AMP11
Costs - £m	64	54	42	3
Typical interventions range from re-builds, membrane installation, rationalisation of storage, refurbishment.				
Estimated volume of storage requiring intervention – 906Ml				

5.8 Further Details from our Network Strategy

The two tables in Appendix 4 provide more details of the areas considered as part of our strategic review of network assets and performance. They are intended as indication only of our direction of travel at this stage. The first table provides a distillation of our Network Strategy and identifies the key areas we are keen to develop. The second gives an indication of the potential timeline over which we see these activities being undertaken.

5.9 Lead

We identify the risk of lead in the customer area of DWSP; however, this cannot reflect the highly granular nature of lead risk across the buildings supplied.

We recognise the need for a long-term strategy in seeking solutions to the issue of lead. We make proposals in this document that make further moves in this direction, but focus in the short-term on managing risks for vulnerable groups and understanding better potential barriers to future activity. In the context of development of a long-term plan for lead, it became clear that the focus needs to balance the needs for progress in reducing the risk over the coming AMP, with defining the actions that will facilitate the long-term goal. So, research and development are a key requirement, alongside activity to identify the changes needed to local and national policy in the areas of housing and public health.

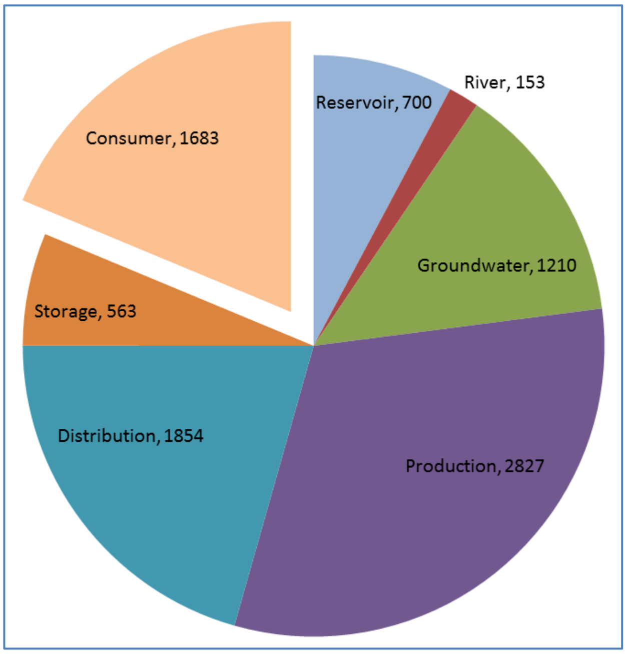


Figure. 39: Number of consumer risks in DWSP (Includes lead).

5.9.1 AMP7 Plans for lead

We outlined our short to medium term plans for progress in dealing with the risk posed by lead within our AMP7 submission to DWI. Our AMP7 approach to lead has 5 main elements to it. These address specific areas of higher risk and we promoted plans to work in the following areas:

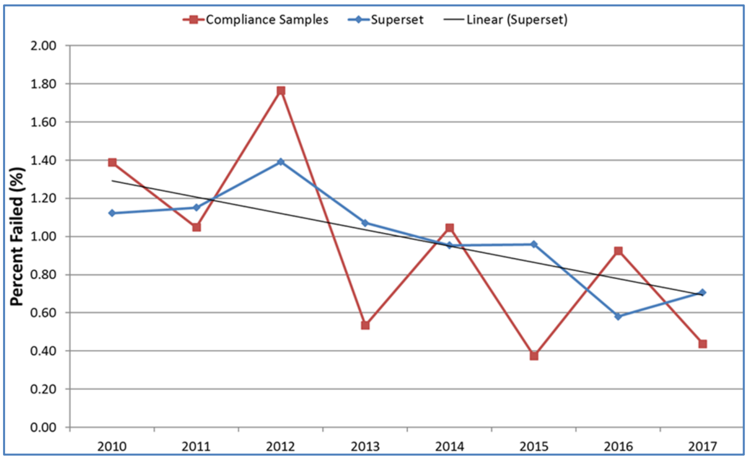


Figure. 40: Continued improvement in lead compliance – 2010-2017.

Vulnerable Customers

- The intention is to continue to work with our vulnerable customers in a targeted rehabilitation or replacement of lead services. Where it is identified that these properties may have a lead service, our intention is to replace / rehabilitate the communication pipe. Where the customer approves, and it is possible to do so from a practical perspective, we will aim to also replace / rehabilitate their supply pipe as well. Based upon the data we have, we expect to renew / rehabilitate approximately 5,000 communication pipes (and where possible, supply pipes as well).

Centres of Education in Yorkshire

- We acknowledge that children are particularly vulnerable to the effects of lead, and that even relatively low levels of exposure can cause serious damage. In the Yorkshire region, in order to reduce a child's potential exposure to lead we plan a programme of renewal / rehabilitation of lead communication pipes, and where agreed, supply pipes, that supply our schools and possibly nurseries.

Replacement on exceedance of the 10µg/l standard

- Under Regulation 17(9), we replace our pipes and fittings where a sample has exceeded the 10µg/l standard.

Lead pipe replacement – customer request scheme

- In line with the our 'Lead Replacement Policy', we fund the "free and matching" replacement of the lead communication pipes at the request of the customers who have replaced all sections of lead in their supply pipe or internal plumbing system.

Opportunistic Replacement of services

- Throughout AMP7, as part of our leakage reduction strategy, we will be focusing on reducing leakage from service pipes; this will result in a more proactive approach to communication pipe replacement. This could result in a couple of possible outcomes. The first being that we replace communication pipes whilst we are carrying out the proactive replacement of distribution mains, or we have a proactive replacement strategy of communication pipes. Both options will reduce exposure to lead, as lead communication pipes will be replaced as part of the strategy.

5.9.2 Plumbosolvency Control Measures

In the short and medium-term customer advice will highlight the potential risks posed by lead services and the requirement to flush after periods of low use. We keep our plumbosolvency control measures under regular review, and within AMP6 will have further reduced the levels of dissolved organics in the output of two significant treatment works which will reduce the plumbosolvency risks further. This has reduced the risk over time to customers with lead pipes as the graph to the right indicates.

In addition, we will follow the following principles: -

- **Short Term**

  Continued review of pH & phosphate levels, plumbosolvency control data, and WTW performance with respect to organics, are carried out on a routine and regular basis. We carry out regular onsite tests at each WTW, and an additional number of operational lead samples over and above the regulatory sampling programme to confirm the efficacy of the measures.

- **Medium Term**

  We are continuing research into the chemistry of lead to be able to confirm that the plumbosolvency control measures remain appropriate. Our current focus is on confirming the findings of previous investigations regarding links between bulk water chemistry and the minimum achievable lead concentration. This will be followed by research which will look at the conditions favouring the risk of particulate lead formation. Finally, the aim is to investigate the potential of modelling tools to predict the optimal plumbosolvency control conditions more precisely.

- **Long Term**

  We continue to invest in the deeper understanding of the chemistry and structure of the minerals that we rely on for plumbosolvency control as this will be needed, and its efficacy enhanced, until all lead sources are removed from service pipes and internal plumbing systems.

  We have committed to undertaking trials that will inform the future delivery of lead pipe remediation; we will aim to coordinate this across the Industry so that we gather the maximum intelligence to inform the future strategy

5.9.3 Overall proposals with investment requirements

We have a strong history of innovation in mitigating lead risk; as early adopters of phosphate dosing; and co-developers of a lining technique that give further options to water companies to reduce exposure to lead.

At the time of writing there is a need for the development of a long-term national strategy for lead, bringing together the key sectors who would be impacted. we believe that it would be inappropriate to continue widespread communication pipe lining or replacement until an agreed strategic approach is identified. We will play our part in the development of a future focussed approach, but are clear that this must be in the context that this is a societal issue and not one solely for the Water Industry.

5.9.4 Research and planning needs to Inform a future strategy for lead

There are two key outcomes which we believe the Industry, Regulators, Public Health and Government should adopt as driving the future:

- Removal of lead risk due to external and internal pipework and fittings
- Cessation of phosphate dosing

The first years of AMP7 should be utilised be to undertake targeted research focusing on driving better understanding in the following key areas:

- Understanding Vulnerable customers – especially those requiring continuous supply or registered for home dialysis.
- Reasons for failures at 10µg/l and above.
- Further large-scale trial(s) – for example to identify factors when remediating lead pipes within social, private rented and owner-occupied housing.
- Research and development into areas such as “extending the length capabilities of lining” and “novel approaches to lead pipe replacement”.
- Maximising the benefits from and understanding of parameters that impact on plumbosolvency control – a crystal structural approach to this key medium-term protection for public health.
- Gathering the base data on which future plans would rely – eg better intelligence on the occurance of external lead pipe / understanding the amounts of lead pipe & lead containing fittings which remain in properties

We are clear that this is a time of change for the Industry, its regulators and health professionals and are committed to working to deliver the information needed to support a future approach to lead. We would welcome further discussion with DWI and others, to identify the best use of investment in this area of water quality enhancement for the future. We are pleased that a very long-term, inter-generational approach to lead has been proposed by DWI. We trust that this will be picked up by Ofwat, other government departments, and local and health authorities to facilitate real progress on this challenging subject.

The activity to reduce lead risks for AMP7 is largely defined in our Business Plan; however, we believe that there are now around 4 years for the Industry, its Regulators and other Government departments to develop the plans for AMP8 onwards with the following aims:

- Identifying a strategy which ultimately allows for the cessation of phosphate dosing and its resource and environmental concerns.
- Understanding the impact of the revised standard in the Drinking Water Directive – if confirmed.
- Understanding the potential lifetime of lining systems for lead pipes – to inform a cost-benefit analysis of this less-disruptive solution.
- Defining whether as a nation we are seeking to achieve compliance, or the protection of public health, and especially the health of children – our future generations.

- Defining the timescale and mechanisms by which the chosen approach will be delivered, and how it will be funded.

In order to plan effectively, these considerations need to be reviewed and the strategy developed by no later than Year 2 of AMP7. To assist in the beginning of the conversation we have identified the approximate costs of delivering a programme of lead service pipe replacement/lining over 20, 40 and 60-year scenarios. To be clear, this does not include for the removal of internal lead pipework and lead donating fittings from premises.

Table 10: Approximate costs of delivering a programme of lead service pipe replacement/lining over 20, 40 and 60-year scenarios.

Scenario & Cost	AMP7				
	1	2	3	4	5
25 year scenario - numbers	50868	50868	50868	50868	50868
40 year scenario - numbers	31793	31793	31793	31793	31793
60 year scenario - numbers	21195	21195	21195	21195	21195
25 year scenario - costs	£ 70,961,250.60	£ 70,961,250.60	£ 70,961,250.60	£ 70,961,250.60	£ 70,961,250.60
40 year scenario - costs	£ 44,350,781.63	£ 44,350,781.63	£ 44,350,781.63	£ 44,350,781.63	£ 44,350,781.63
60 year scenario - costs	£ 29,567,187.75	£ 29,567,187.75	£ 29,567,187.75	£ 29,567,187.75	£ 29,567,187.75
Cost per AMP - 25 year	£				354,806,253.00
Cost per AMP - 40 year	£				221,753,908.13
Cost per AMP - 60 year	£				147,835,938.75

These costs are effectively a means of delivery of compliance for the lead parameter; but infers a cost per AMP over 12 AMPs more than double the value to our AMP7 Quality Programme with a total spend of £1,774m; when spread over 5 AMPs of the costs are similar overall, but rise to 5 times our AMP7 Q spend per AMP, Existing research suggests that even with a standard of 5µg/l for as long as phosphate dosing continues this would be sufficient to deliver compliance in the vast majority of scenarios.

Much additional data on the prevalence of lead pipe and fitting remaining within properties is required to understand the risks to residents, especially children, of removing phosphate dosing whilst these lead donors remain.

6.0 Operational Resilience

In section 2.3 we outlined the activity undertaken by Arup in assessing the high-level resilience of our corporate systems and its application to the components of our source to tap activities. To support this activity and allow us to understand in detail the resilience at water supply system level, Stantec were appointed to work with our teams on an approach that allows a consistent means of assessment of operational resilience using a whole system approach.

6.1 Operational resilience

We have identified key actions which will allow us to deliver more reliable and resilient water production. This is focused on the key areas of maintenance and the prevention of and recovery from equipment failure to improve reliability, including:

- Good practice in maintaining assets, in particular for dosing systems and monitoring and control systems.
- Pro-active preventative replacement strategies and / or fail-safe back up facilities to reduce risk.
- Improved reliability and use of on-line monitoring systems to improve responsiveness.
- Developing a plan to retro-fit run to waste systems on all WTW.

To achieve these challenging internal targets, will require us to review our processes, including maintenance; control room alarm handling; incident response; promotion; planning and scheduling of work, as well as water resource allocation planning and water quality procedures and processes. In order to build our resilience further, we will take a predictive and proactive approach to WTWs maintenance; improving asset stability, reducing down-time and increasing asset availability. This will be supported by trials of a new operating model at five of our critical sites, where there will be additional focus on availability and process safety.

6.2 Stantec Operational Resilience study of the Water Supply Systems of Yorkshire

In Spring 2017 Stantec (MWH) were appointed to undertake a review of the resilience of a selection of our water supply systems, seventeen have been reviewed, which cover around 50-60% of the population of the Company's water supply operational area.

Vulnerability assessments have been completed to allow the ranking of these sites to prioritise interventions. The assessments considered the following key service indicators and risk factors:

- Properties at Risk
- Equivalent no. of props without alternative supply
- System Redundancy Shortfall (% of customers who can't be supplied from elsewhere)
- "Survival" Time (time supplies can be maintained using storage and rezoning (hrs))

- Likelihood of outage exceeding "Survival" time (during next 10 years)
- Customer minutes lost impact (per hour if outage duration exceeds "Survival" time)
- Current Reliability (based on annual unplanned outage volume as % of capacity)
- Safe Restart (Is site able to run to waste to allow safe restart)
- Overall Resilience Risk Ranking (within the 17 sites reviewed)

The intention is to complete the review of the remaining systems by the end of 2018. Our plan is to identify a range of potential solutions for investigation and optioneering during AMP7, to provide inputs to PR24 and beyond.

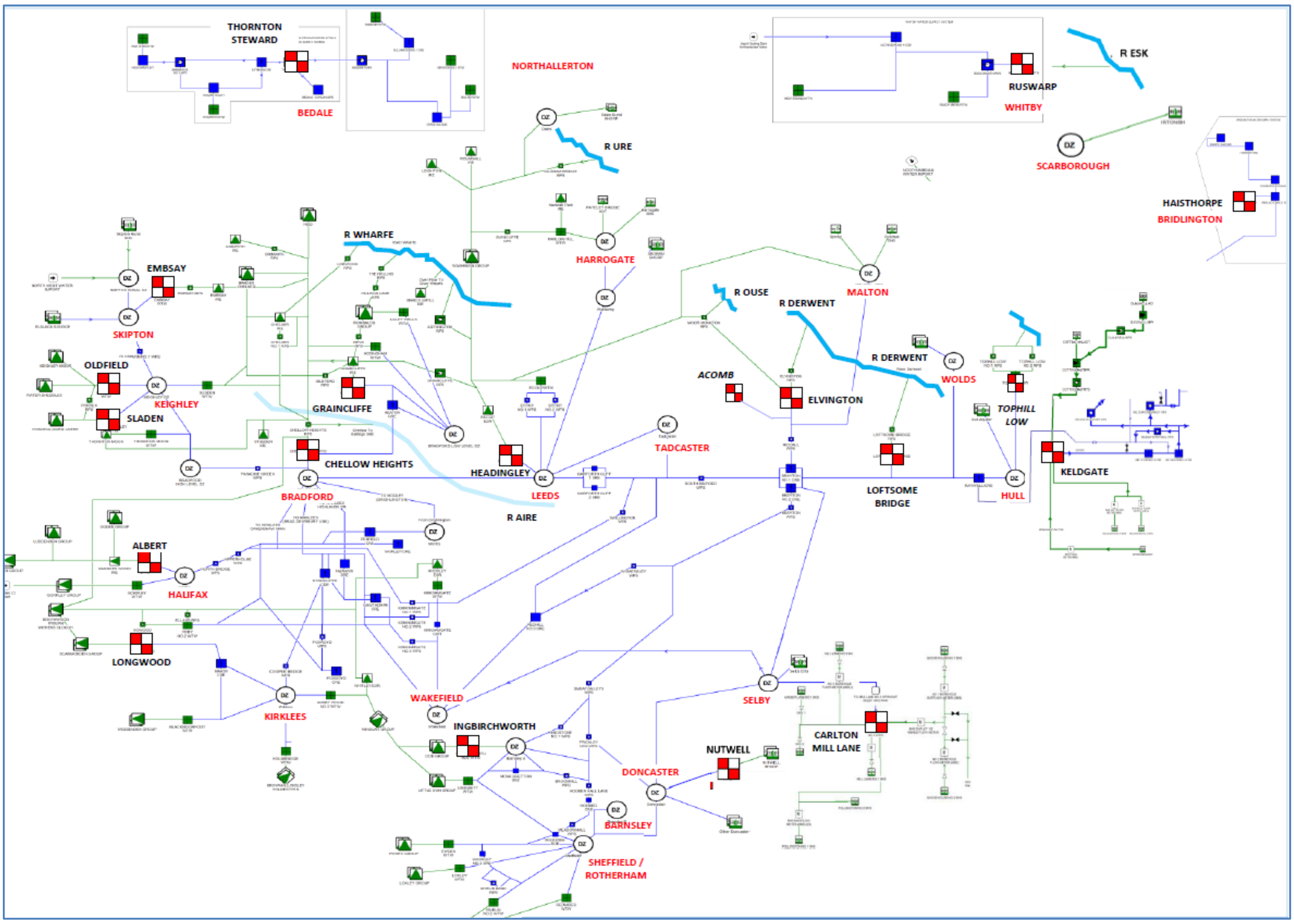


Figure. 41: Water Supply Systems reviewed by Stantec.

Water Supply System Resilience Dashboards have been created to allow ease of review and interrogation of outputs. Thresholds and descriptors have been set up within the dashboard, which can be modified to reflect any current or future agreed standards or strategic principles. The dashboard view allows quick and easy identification of any current and future shortfalls, and a risk-based approach to delivering resilient services in the long-term.

Yorkshire Water - Water Supply System Resilience Dashboard

Site Name	Chellow		Works Capacity (Ml/d)		175		Typical Availability average % of capacity which can be deployed at any time		92%	Slightly Low	Resilience risk score at Chellow relative to total risk (for all 17 sites reviewed) 15.2 %	
Equivalent Properties Supplied / Average Output	328,300	140.4 Ml/d average output	Properties at Risk / Deficit Equivalent nr of props without alternative supply / shortfall in supply		234,000	100 Ml/d deficit	System Redundancy Shortfall (% of customers can't be supplied from elsewhere)		71%	Serious Shortfall		
"Survival" Time time supplies can be maintained using storage and rezoning (hrs)	48	Tolerable	Likelihood of outage exceeding "Survival' time (during next 10 years)		Likely		Customer minutes lost impact (per hour if outage duration exceeds "Survival' time)		7.1	Very Severe Concern		
Current Reliability based on annual unplanned outage volume as % of capacity	100%	Tolerable	Safe Restart Is site able to run to waste to allow safe restart		No		Overall Resilience Risk Ranking (within the 17 sites reviewed)		2nd Highest Resilience Risk			
Potential Solutions	Beneficial Impact	Delivery Risk	Increase in Storage (Ml)	Alternative Supply / Production (ML/d)	Residual Nr of Properties with no Alternative Supply	Revised Survival Time Available (Hrs)	Revised Likelihood of outage exceeding "Survival' time	Revised CML impact	Scale of Cost to Deliver	How much would proposed solution reduce current risk	VFM Measure (cost £ per 1% reduction in risk)	Overall VFM Rank

Figure. 42: Example of Water Supply System Resilience Dashboard.

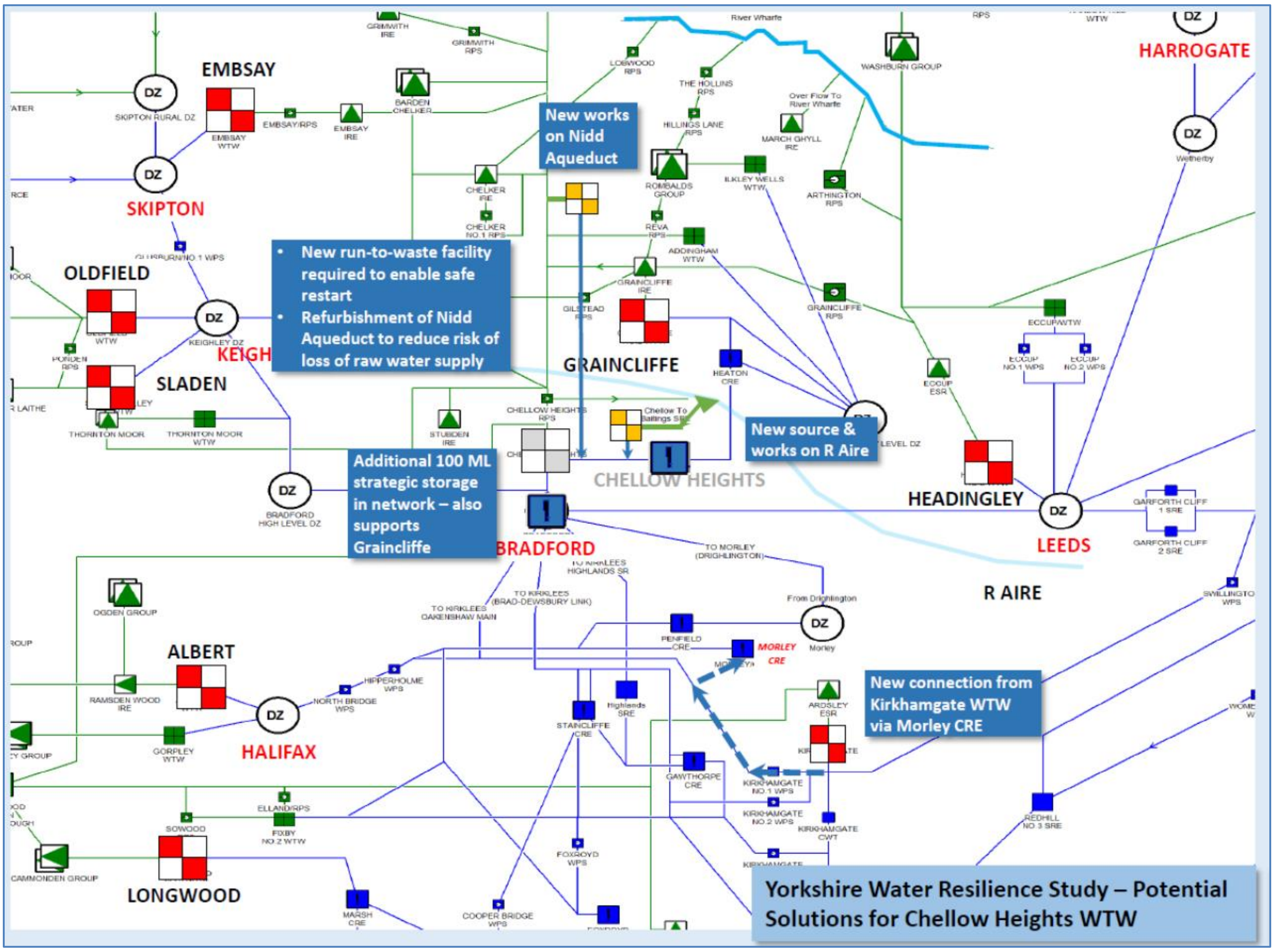


Figure. 43: Chellow Water Supply System: Overview of potential interventions to improve system resilience.

Potential solutions to resilience shortfalls are displayed on a source to tap schematic which allows the visualisation of potential connectivity within and between water supply systems. These are then able to be compared for the system under consideration, and across all systems to identify an optimal approach to enhancing resilience.

We are currently planning to extend this review to all water supply systems so that this can form the basis of investigations into future solutions during AMP7. Some more limited schemes to enhance resilience are already proposed within AMP7 activities.

The schematic (figure 43) provides an overview of the potential “schemes” identified which would improve the resilience of the Chellow (Bradford) water supply system.

The outputs provided include a diverse range of options for mitigation, and it may be on further examination that combinations of options over time provide the optimal solution, especially when looked at in conjunction with those for adjacent areas.

Appendices

Appendix 1 – Leeds University Research – Colour/DOC

Based on long-term observational data, most studies in Europe, which previously experienced high loads of Sulphur (S) deposition, have identified recovery from acid rain as the main driver of DOC trend. This has led to theories of solubility control mechanisms on DOC that have since been supported by field and laboratory experiments. In the UK, S deposition declined by 80% between 1986 and 2006 to 1 Mt SO2 yr-1. By 2021, a further 50% reduction in SO2 deposition is expected. It might therefore be expected that no further increase in surface water DOC concentrations, as a result of this mechanism, is likely given that S deposition has reached such low levels. However, peat and organomineral soils have accumulated large amounts of deposited S in organic and inorganic binding forms over the last 100 years. This S is likely to be oxidised to SO4 during droughts leading to episodic acidification of soils and a reduction in surface water DOC followed by a potential increase in DOC once the drought has passed. In contrast, theories of a temperature control on DOC production have first arisen from controlled laboratory experiments on decomposition. However, the amount of DOC available for export to surface waters will depend, in part, on how temperature affects the difference between DOC production and DOC respiration (loss to CO2), which is also likely to increase with rise in temperature and/or extended periods of drought in highly organic soils, as this difference controls the pool of DOC available for export from the soil (Schiff et al., 1997). In addition, it is the availability of water that controls when and how much of the available soil DOC pool is transported to surface waters. An increase in temperature is also likely to lead to an increase in the growing season, resulting in increased primary production and potentially a larger pool of recently fixed carbon. In the longer term, warmer temperatures will lead to a change in vegetation composition.
The timing of precipitation events strongly influences the delivery of DOC to surface water and has been shown to drive year-to-year fluctuations. To date, however, there is no evidence to implicate a change in precipitation totals or periodicity or intensity as a driver in long-term DOC trend at UK sites. Of the four major land managements reviewed in this report it can be concluded that;

- Grazing has no impact on DOC, despite leading to a change in vegetation composition.
- While afforestation leads to an increase in DOC in soil solutions from the organic horizon, no consistent impact is observed in surface waters at the catchment scale. In addition, DOC trends have been found to be similar for adjacent forested and moorland catchments.
- Small differences in DOC concentrations occur between drained and blocked peatlands at the local scale (soil solution, drain), but more evidence is needed at larger spatial and longer temporal scales.
- The balance of evidence suggests that heather burning has a negative effect on water colour and DOC release to stream waters, but longer-term records are needed.

Statistical models have proved invaluable in identifying possible key drivers of long-term DOC change and to a limited extent in quantifying the contribution of individual drivers. The evidence from statistical models suggests dominant drivers may differ between forested and peat-dominated catchments, between lakes and streams, and between regions with or without a significant snow-melt influence, and that catchment geomorphology through its influence on soil formation and hydrology, may attenuate a regional-scale effect.

Water colour has increased significantly at 10 of the 11 YW sites studied over the period 1987-2015 and at six of the 14 sites over the period 1998-2015.

The statistical model predicted for Keighley Moor, using realistic scenarios of future SO2 emissions and summer rainfall, that mean annual water colour is likely to stabilize in the period to 2030, with predictions for the wettest summer rainfall scenarios (50-year and 100-year events) delivering annual mean colour that is similar to that observed for the wettest year on record (2012, mean = 172 Hazen). Results from INCA-C, using two different rainfall datasets, predicted that mean monthly DOC concentrations will be very similar in the 2030s as they have been in the period 2010-2015 and between 20 and 24% higher by the 2080s. Thus, both modelling approaches suggest that the most rapid increases in DOC/water colour have been observed. The statistical model has suggested that wet summers will lead to higher DOC/water colour and INCA-C shows the impact of increasing temperature on DOC production and thus increase in DOC/water colour in the 2080s.

As the top metre of peat can contain as much as 10 000 kg S ha-1 (Miller et al., 1996), mobilization and loss of sulphur (that has accumulated from atmospheric deposition) from the peat during droughts is likely to be a slow process. Thus, droughts are likely to lead to a suppression of DOC/water colour for the foreseeable future. Intense rainfall events, especially in the summer, are likely to lead to an increase in DOC/water colour as the humic acids are washed out of the soil, as observed in 2012.

Why is water colour so high in the Yorkshire Region?

Firstly, a large proportion of blanket found in England and Wales is within the YW region (see Table 2 in report by Chapman et al., 2017 – part 1). The three regions in Table 2 that lie within the YW region (bold and italics) accounts for 34% of all blanket peatland in England and Wales. More coloured water, with high concentrations of DOC, is observed in catchments with a high proportion of organic soils such as peat as this controls the size of the carbon pool that is available for export (Chapman et al., 2017 – part 1).

Table 2. Distribution of blanket peat in upland areas of England and Wales in comparison to whole of Scotland (adapted from Clark et al., 2010)

Upland region	**Area of blanket peat (km^2)**	**% of total in Great Britain**
North York Moors	***40***	***0.3***
Brecon Beacons & S. Wales	52	0.3
Dartmoor, Exmoor & Bodmin moor	146	0.9
Cumbria Fells & Dales	182	1.2
Cambrian Mountains, Wales	209	1.3
Northumbria	325	2.1
Peak District	***476***	***3.0***
Snowdonia & N. Wales	718	4.5
Yorkshire Dales & Bowland	***765***	***4.8***
Total	3604	22.8
Scotland	12226	77.2

Secondly the blanket peat in Yorkshire is highly degraded. Soil degradation occurs when human-induced phenomena lower the current and/or future capacity of the soil to support vegetation and animal life. Soils are generally resilient to change within certain limits, but outside these limits the soil will not recover naturally even if the pressure is removed. Most organic soils support ecosystems that are sensitive to pollutant impacts and human activities; hence these soils are very susceptible to degradation. Peatland degradation is often characterised by:

- A reduction in species diversity.
- A reduction in the cover of *Sphagnum* species compared to the historic past.
- An increase in the area of discontinuous plant cover (bare peat).
- A reduction in the rate of peat accumulation due to decline in water table and *Sphagnum* species.

In addition to direct human activities, climate change may trigger these characteristics by upsetting the delicate hydrological balance of organic soils.

Thirdly the climate in Yorkshire, which is warmer than more northern blanket peats e.g. Scotland, means that decomposition rates are higher and thus more DOC/colour produced. Also, high rainfall in the west of region means that peat and river network is well connected and DOC that is produced in the peat is delivered to surface waters. A warm and wet climate is ideal for colour production and delivery to surface waters.

Lastly, the geology of the Pennines means that blanket peat covers the top of the catchments, whereas in Wales and Scotland catchments contain larger areas of steeper land where soils on the high ground are thin. This results in catchments which do not contain such high proportion of exposed deep blanket peat, and do not contain so much carbon. In addition, in the Yorkshire region, the natural drainage networks seem much denser and the stream channels much deeper (steep banks) in the Pennines, which perhaps mean shorter/better connectivity between the organic soils and streams than other upland areas.

The peat soils in Yorkshire are particularly vulnerable to degradation due to a combination of the following reasons:

- Surrounded by highly populated areas e.g. Manchester, Sheffield, Leeds, so they have been extensively used by humans for farming, recreation and game birds with subsequent disturbance effects (erosion, artificial drainage, heather burning, modified vegetation cover etc.).
- For the same reason they have been highly impacted by current and past pollution, especially acid rain and heavy metal deposition.
- Peat in this region is climatically vulnerable as it sites at the lower edge of the bioclimatic envelope, based on models that include measures of both hydrological conditions and maximum temperature under scenarios of climate change (Clark et al., 2010).

Overall, the blanket peat in YW region has been heavily grazed by sheep, intensively drained, heather has been burnt for grouse management. For example, in the Yorkshire Dales National Park approximately 60 % of peat moorland has been subjected to machine ditching (Backshall et al., 2001).

Degradation of the peat results in:

- Increased erosion and loss of particulate peat into river courses and reservoirs, where it is deposited resulting in lower water holding capacity of the reservoir
- Increased decomposition of the peat as the water table is lower and decomposition is faster in aerobic conditions than anaerobic (see Chapman et al 2017 – part 1). This result in loss of carbon to the atmosphere as

carbon dioxide (CO_2) and particulate and dissolved organic carbon (POC & DOC) to the aquatic ecosystem (and thus water becomes more coloured).

Why is peatland restoration a good thing?

The Peat moorlands are particularly important in our region because they are the source catchments for a large

proportion of our drinking water. Our research with Leeds University (2012[27]) concluded that the climate will not be suitable for peat moorlands within Yorkshire by 2050 under the 2009 UK climate projections 'high emissions scenario', and by 2080 under the 'low emissions scenario'. That does not mean that the peat moorlands in the region will disappear, it indicates they may become more prone to erosion and have the potential to cause large water quality problems in the future. The review found that management interventions can be effective but are likely to take a number of years for the benefits to be manifested.

Restoration of peatlands, via a number of mechanisms as outlined below, can result in the following:

1. Increased vegetation cover (reseeding of bare peat)

- Diverse vegetation cover including large proportion of sphagnum slows the flow of water across catchment. This reduces runoff and downstream flooding (see Holden et al, 2012; Gao et al., 2017). It also reduces flux of high DOC/coloured water by optimising microbial degradation of DOC prior to arriving at WTWs (Holden et al., 2013).
- Diverse vegetation cover stabilises soil temperature and controls microbial production of DOC potentially resulting from increase in air temperature.
- Complete vegetation cover reduces erosion of particulate organic carbon (POC) which can be deposited in reservoirs and transformed to DOC/colour in river network

2. Blocking of drainage ditches

- Raises water table which (i) slows the flow of water from catchment and (ii) results in decline in decomposition of peat to DOC and CO_2 (Chapman et al., 2017 part 1)
- Reduces peat erosion and loss of particulate organic carbon (POC)

3. Maintaining a more stable water table that is nearer to the peat surface

- High water table able to buffer effects of drying-wetting cycles that produce colour/DOC
- Drought = lowering of water table. If water table higher then get fewer large droughts. If water table low (degraded) then get more droughts and increase in water colour

Therefore, restoration of the peatland can:

- 1. Mitigate against climate change, as less CO_2 emitted to atmosphere (carbon is stored in peat).
- 2. Reduce water colour production via decomposition
- 3. Reduce peat erosion into reservoirs and river systems
- 4. Slow the flow (water flows more slowly across the catchment) and helps reduce downstream flooding.

Appendix 1a – Arup research on nitrate

The nitrate investigation was to better understand the complete nitrate cycle and to identify effective catchment management approaches to inform a long-term sustainable nitrate management strategy for groundwater abstraction. The investigation was three-fold, with Parts 1 and 2 of the programme focusing on the potential sources of (apportionment) and pathways for (transportation/storage) of nitrate in the catchment. The findings from those studies was then used to inform the work undertaken in Part 3, which focuses on the identification of the most suitable catchment management options. The aim of the investigation was to provide the technical and hydrogeological understanding needed to improve and target appropriate interventions and to communicate more effectively with project stakeholders, particularly farmers and landowners.

Experience from the three pilot catchments showed that geology and recharge processes can vary significantly between catchments even when they are located on the same bedrock aquifer. It is therefore recommended that it will be worth repeating the characterisation across all 17 of YWs nitrate safeguard zones. The study also identified and quantified the sources of nitrate in each catchment. Sources of nitrate considered included agriculture, sewage sludge spreading, leaking sewers, septic tanks, mains water, urban land uses, landfills, cemeteries, pollution incidents, licenced discharges to groundwater and precipitation.

The sandstone boreholes with deeper abstraction zones are associated with lower nitrate concentrations. Furthermore, the abstraction rate may influence the nitrate concentrations as higher abstraction rates tend to result in higher nitrate concentrations in the outflow. It is likely that this is due to the increase in the cone of depression resulting in an increase in flow from shallower higher nitrate waters.

Groundwater age data, measured from Sulphur Hexafloride (SF6) analysis, suggests that the average groundwater age at the Chalk abstractions at Kilham is more recent than in the sandstone abstractions, at Heck and Pollington and Armthorpe. This indicates that any catchment management interventions in the chalk catchments may be realised faster than in the sandstone catchments. Results also highlighted there will likely be a time lag associated with any proposed intervention implemented in the catchments as indicated by the groundwater age data.

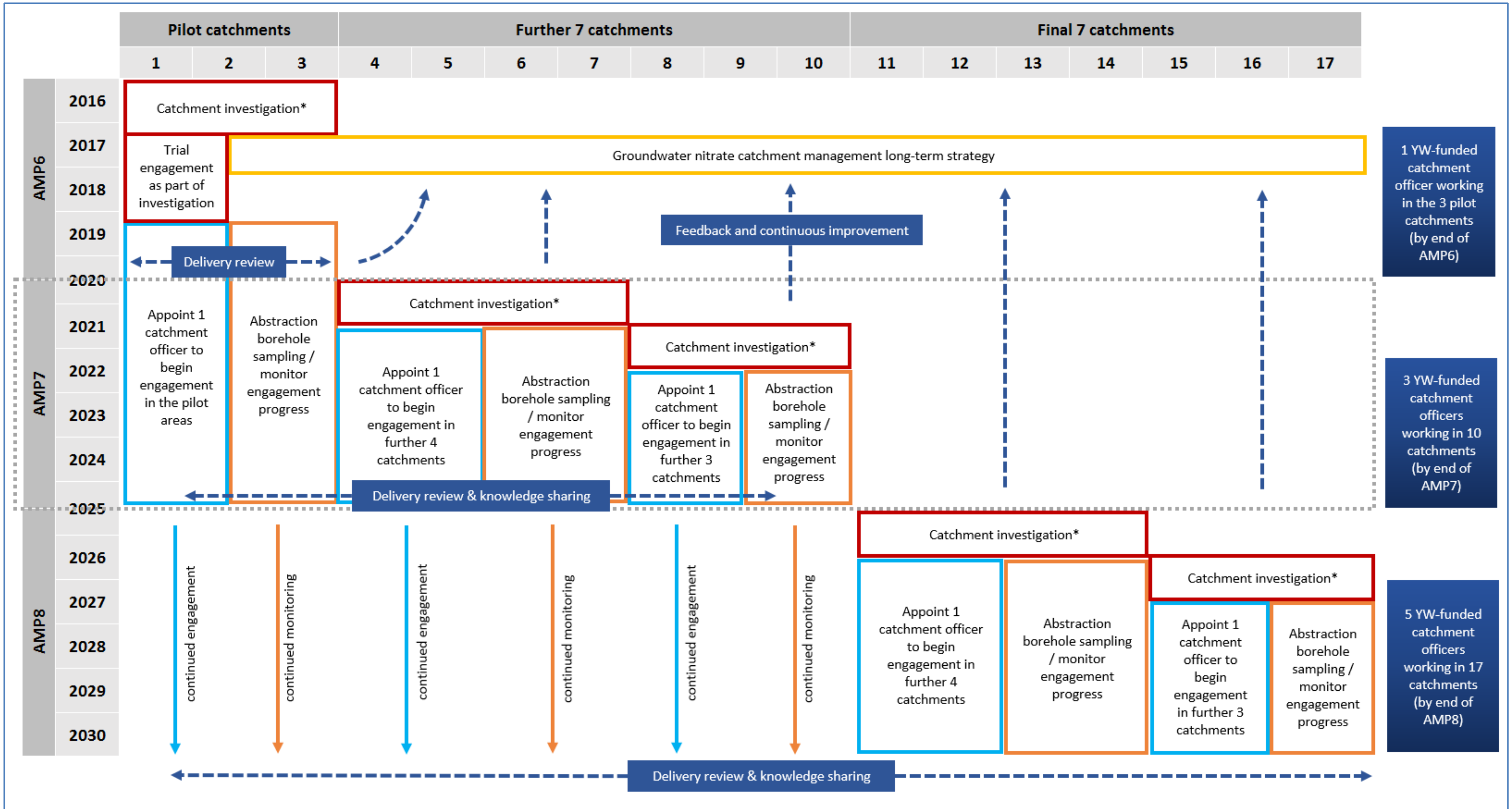
Appendix 2a - Catchment Strategy

AMP7	AMP8	AMP9	AMP10	AMP11
• Investigate remote sensing, telemetry and control for raw water quality management – esp. colour/DOC • Identify appropriate remote sensing techniques to identify catchment areas for repair / restoration, and monitor impact of intervention • Undertake incremental catchment repair/restoration works as defined in WINEP • Research impacts of landscape restoration on colour/DBP – ie define the ultimate catchment state required for RWQ • Research maintenance needs of restored peat catchments • Identify vegetation control solutions to "no-burning" scenarios	• Implement remote sensing, telemetry and control for raw water quality management – esp. colour/DOC – phased approach • Implement remote sensing techniques to identify catchment areas for repair / restoration, and monitor impact of intervention • Undertake incremental catchment repair/restoration works as identified by research • Research impacts of landscape restoration on colour/DBP – ie define the ultimate catchment state required for RWQ • Research maintenance needs of restored peat catchments	• Implement remote sensing, telemetry and control for raw water quality management – esp. colour/DOC – phased approach • Implement remote sensing techniques to identify catchment areas for repair / restoration, and monitor impact of intervention • Undertake incremental catchment repair/restoration works as identified by survey and data • Research impacts of landscape restoration on colour/DBP – ie define the ultimate catchment state required for RWQ • Research maintenance needs of restored peat catchments	• Implement remote sensing, telemetry and control for raw water quality management – esp. colour/DOC – phased approach • Implement remote sensing techniques to identify catchment areas for repair / restoration, and monitor impact of intervention • • Undertake incremental catchment repair/restoration works as identified by survey and data • Research impacts of landscape restoration on colour/DBP – ie define the ultimate catchment state required for RWQ • Research maintenance needs of restored peat catchments	• Implement remote sensing techniques to identify catchment areas for repair / restoration, and monitor impact of intervention • • Undertake incremental catchment repair/restoration works as identified by survey and data • Research impacts of landscape restoration on colour/DBP – ie define the ultimate catchment state required for RWQ • Research maintenance needs of restored peat catchments • implement vegetation control solutions to "no-burning" scenarios • • Research to identify optimal land use to minimise colour/DOC generation

• Research to identify optimal land use to minimise colour/DOC generation • Research to identify extent of DOC processing within streams, pools, RW storage, and transmission • Investigate carbon sequestration approach as a means to resource catchment improvement and maintenance • Undertake nitrate catchment management at: Wolds and Hull boreholes, Doncaster Groundwater and Selby sites • Investigate opportunities to reduce requirement for mineral-N – eg N-Fix trials in Yorkshire • Review pesticide use trends and work with others to mitigate potential impacts at source	• implement vegetation control solutions to "no-burning" scenarios • Research to identify optimal land use to minimise colour/DOC generation • Trial solutions to deliver DOC processing within streams, pools, RW storage, and transmission • Investigate carbon sequestration approach as a means to resource catchment improvement and maintenance • maintain nitrate catchment management at: Wolds and Hull boreholes, Doncaster Groundwater and Selby sites • Implement opportunities to reduce requirement for mineral-N – eg N-Fix trials in Yorkshire • Review pesticide use trends and work with others to mitigate potential impacts at source	• implement vegetation control solutions to "no-burning" scenarios • Research to identify optimal land use to minimise colour/DOC generation • Deliver solutions to deliver DOC processing within streams, pools, RW storage, and transmission • Investigate carbon sequestration approach as a means to resource catchment improvement and maintenance • maintain nitrate catchment management at: Wolds and Hull boreholes, Doncaster Groundwater and Selby sites • Implement opportunities to reduce requirement for mineral-N – eg N-Fix trials in Yorkshire • Review pesticide use trends and work with others to mitigate	• implement vegetation control solutions to "no-burning" scenarios • Research to identify optimal land use to minimise colour/DOC generation • Deliver solutions to deliver DOC processing within streams, pools, RW storage, and transmission • Investigate carbon sequestration approach as a means to resource catchment improvement and maintenance • maintain nitrate catchment management at: Wolds and Hull boreholes, Doncaster Groundwater and Selby sites • Implement opportunities to reduce requirement for mineral-N – eg N-Fix trials in Yorkshire • Review pesticide use trends and work with others to mitigate	• Deliver solutions to deliver DOC processing within streams, pools, RW storage, and transmission • Investigate carbon sequestration approach as a means to resource catchment improvement and maintenance • maintain nitrate catchment management at: Wolds and Hull boreholes, Doncaster Groundwater and Selby sites • Implement opportunities to reduce requirement for mineral-N – eg N-Fix trials in Yorkshire • Review pesticide use trends and work with others to mitigate potential impacts at source •

		potential impacts at source	potential impacts at source	

Appendix 2b - Catchment Strategy – Nitrate specific



*Catchment investigation includes land use assessment, source apportionment, geological and hydrological characterisation

Appendix 3 - Treatment Strategy

AMP7	AMP8	AMP9	AMP10	AMP11
• Zero unplanned shutdowns - Reduction of 80% to 150 pa. • WTW capable of treating all available resource to required standard - 40% of works to achieve maximum flow • Investigate remote monitoring and telemetry for raw water quality data – esp. colour/DOC • Investigate structural stability of Elvington weir – agree plan with EA • %age of useable headroom matched to demand centres or individual sites - WRMP • 100% WQ compliance - Achieve 99.97% Water Quality compliance • Investigate removal of DBPs at Longwood, Loxley • *Investigate removal of Metaldehyde at: Elvington, Acomb Landing, Huby,*	• Zero unplanned shutdowns - Reduce from 150 to 75 pa. • WTWs capable of treating all available resource to required standard - 75% of works to achieve maximum flow • %age of useable headroom matched to demand centres or individual sites - WRMP • 100% WQ compliance - Achieve 99.98% Water Quality compliance • 2no. Sites (Longwood, BMF) need DBP investment (based on current predictions) • *Removal of Metaldehyde at all sites (alternative sources / treatment)* • Nitrate treatment at Haisthorpe – subject to degree of success	• Zero unplanned shutdowns - Reduce from 75 - 50 pa. • WTWs capable of treating all available resource to required standard - 90% of works to achieve maximum flow • %age of useable headroom matched to demand centres or individual sites - WRMP • 100% WQ compliance - Achieve 99.99% Water Quality compliance • 2no. Sites (Fixby and BMF) need DBP investment (based on current trends) • Delivery of pesticide removal at Carlton Mill Lane – subject to outcome of source investigations in AMP7 WINEP • Potential further sub-regional	• Zero unplanned shutdowns - Reduce from 50 - 40 pa. • WTWs capable of treating all available resource to required standard - 95% of works to achieve maximum flow • %age of useable headroom matched to demand centres or individual sites - WRMP • 100% WQ compliance - Achieve 99.995% Water Quality compliance • 2no. Sites (Chellow (additional streams) and Albert) need DBP investment (based on current trends)	• Zero unplanned shutdowns - Reduce from 40 - 30 pa. • WTWs capable of treating all available resource to required standard - 95% of works to achieve maximum flow • %age of useable headroom matched to demand centres or individual sites - WRMP • 100% WQ compliance - Achieve 99.998% Water Quality compliance

Loftsome Bridge, Eccup2, Tophill Low • Investigate algal control at: Thornton Steward, Ingbirchworth, Loftsome Bridge, Tophill Low • CIP (Chemical Investigation Programme) research – review implications for DW safety • New DBPs of concern – undertake review of recent research to identify treatment needs for AMP8 and beyond • Membrane replacements required • Investigate sources of Pesticides at: Carlton Mill Lane – AMP7 WINEP • Investigate feasibility/location for possible new borehole at Heck – nitrate blending • Research alternative DOC removal techniques	in engaging CM activities in SPZs • Further blending (nitrate) at CML, Heck & Cowick • Deliver Algae risk reduction schemes at: Loftsome Bridge, Thornton Steward, Ingbirchworth, Tophill Low • Investigate need for pesticide removal at Carlton Mill Lane – subject to outcome of source investigations in AMP7 WINEP • Manganese removal at Ainderby • Potential sub-regional chloramination for T&O management	chloramination for T&O management		

Appendix 4 – Network Strategy

	Trunk Mains	Service Reservoirs & Pumps	Distribution Mains	Service Pipes	Customer Meters	Other
Water Quality **Long term target: Significant improvement in Risk of discolouration, TIM Failures, SR compliance, Lead**	-Where feasible implement automatic trunk mains conditioning for water quality by start of AMP8 - Where trunk mains conditioning is not feasible investigate options for installation of cross connections, valves, re-zones, etc to enable this or put on re-lining programme by start of AMP8 (ERI will likely become financial penalty only) - Survey air valves to ensure free draining pits	-Enable more real time monitoring in AMP7 to ensure we can maintain stable chlorine and turbidity levels on outlet of SRs with a view to linking to live hydraulic models in AMP9 -Review hydraulic gradient & transients for all SR inlet/outlet mains -Review SR turnover time with winter/summer profiles due to falling leakage levels -Intall enabling works so that all SRs can be taken out for inspection and maintenance -Ensure investment in SR re-builds to maintain stable SR condition	-Use of WAND for all valve operations to assess risk -Improve water quality by targeted DMA flushing programme so the network has no detrimental impact -Use sediment depth model & regeneration rate to priorities flushing and mains renewal/re-lining based on whole life cost rather than customer contacts -Monitor turbidity and chlorine at DMA inlets so customers can be notified of events -Use UKWIR Research on microplastics to understand the risk to human health of microplastics -Understand quantity of cement leached from asbestos cement repairs to identify programme for AC renewal	-Manage pH & phosphate to achieve lead targets -Improve water quality by targeted service pipe lining / renewal (starting with schools, high risk DMAs, vulnerable customers) - Regulation inspections of new build developments to cover internal plumbing & prevent toilet cistern backsyphonage	-Incorporate WQ monitors into smart meter network in AMP8 & beyond	-Need to highlight need for chloramination & WTW Mn reduction -Need to promote a government strategy on removal of lead inside the property

		AMP7	AMP8	AMP9	AMP10	AMP11
Water Quality						
	Trunk Mains	-Where feasible implement automatic trunk mains conditioning for water quality by start of AMP8	- Where trunk mains conditioning is not feasible investigate options for installation of cross connections, valves, re-zones, etc to enable this or put on re-lining programme by start of AMP8 (ERI will likely become financial penalty only)			
	Service Reservoirs & Pumps	-Enable more real time monitoring in AMP7 to ensure we can maintain stable chlorine and turbidity levels on outlet of SRs -Review SR turnover time with winter/summer profiles due to falling leakage levels -Intall enabling works so that all SRs can be taken out for inspection and maintenance -Ensure investment in SR re-builds to maintain stable SR condition	-Ensure investment in SR re-builds to maintain stable SR condition	-Link water quality data from SRs to live hydraulic models enabled by smart metering -Ensure investment in SR re-builds to maintain stable SR condition	-Ensure investment in SR re-builds to maintain stable SR condition	-Ensure investment in SR re-builds to maintain stable SR condition

	Distribution Mains	-Use sediment depth model & regeneration rate to priorities flushing and mains renewal/re-lining based on whole life cost rather than customer contacts -Monitor turbidity and chlorine at DMA inlets so customers can be notified of events -Use UKWIR Research on microplastics to understand the risk to human health of microplastics -Understand quantity of cement leached from asbestos cement repairs to identify programme for AC renewal	-Continue DMA flushing based on regeneration rate -Develop targeted programme for AC renewal	-Continue DMA flushing based on regeneration rate -Programme for AC renewal	-Continue DMA flushing based on regeneration rate -Programme for AC renewal	-Continue DMA flushing based on regeneration rate -Programme for AC renewal
	Service Pipes	-Manage pH & phosphate to achieve lead targets -Improve water quality by targeted service pipe lining / renewal (starting with schools, high risk DMAs, vulnerable customers)	-Manage pH & phosphate to achieve lead targets -Improve water quality by targeted service pipe lining / renewal	-Manage pH & phosphate to achieve lead targets -Improve water quality by targeted service pipe lining / renewal	-Manage pH & phosphate to achieve lead targets -Improve water quality by targeted service pipe lining / renewal	-Manage pH & phosphate to achieve lead targets -Improve water quality by targeted service pipe lining / renewal

	Meters & Other	- Regulation inspections of new build developments to cover internal plumbing & prevent toilet cistern backsyphonage -Highlight need for chloramination & WTW Mn reduction -Promote a government strategy on removal of lead inside the property	-Consider turbidity or chlorine monitors as part of smart metering rollout -Ongoing regulation inspections of new build developments to cover internal plumbing & prevent toilet cistern backsyphonage	-Link water quality monitors to live hydraulic models		

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PR19 - Water Quality Submission

Yorkshire Water Services Ltd

22nd December 2017

Part A

General approach to our Drinking Water Quality Programme

Executive Summary

What is our submission to the Drinking Water Inspectorate?

Our customers have clearly told us that their **number one priority is a reliable supply of clean, good quality water.** They need to know that their water supply is secure, wholesome and sustainable. Our **customers** also want us to **stop failures** in service from affecting their lives. We need to ensure that our water supply system is **resilient.**

These priorities are founded upon nearly **19,000 customer** conversations across a wide range of formats, since 2015. The conversations have helped us understand more about what is important to our **customers** now and in the future. We have talked to our **customers** about how water plays a part in their lives and the dependencies we all have on water.

Our customers' **priority of a reliable supply of clean, good quality water** is reflected in the legislation and regulation for the water industry, which requires us to supply 'wholesome' drinking water quality that is acceptable to consumers. Wholesome is defined in law by strict standards for a wide range of substances, organisms and properties of water. The standards are set to be **protective of public health**. The definition of wholesome reflects the importance of ensuring that water quality is acceptable to consumers.
The Drinking Water Inspectorate (DWI) is the independent regulator of drinking water in England and Wales. The DWI ensures that water companies supply safe drinking water that is acceptable to consumers and meets the standards set down in law.

Our **submission to the DWI** is a key milestone toward meeting our **customers' priorities.** It describes how we will protect and **deliver improved drinking water quality** to our customers in the face of **challenges such as raw water deterioration, pesticide usage in the environment, climate change and the impact of lead pipes connecting many customers to our drinking water supply network.**
We make a submission to the DWI every five years. Our latest submission forms part of a suite of submissions to our regulators for PR19, setting out our **long-term plans** but specifically planning for the period 2020-2025. This submission follows the appropriate guidance from the DWI and the Environment Agency (EA). It will be followed by our Long-term Water Quality Strategy Document in May 2018.

What challenges do we face?

We have **continued to improve both our compliance with drinking water standards and customer acceptability measures** in recent years. We have achieved this through targeted improvement schemes and the placement of additional operational controls on our catchments (which are the areas where water is collected by the natural environment), treatment facilities, water storage and pipe networks. We have **ambitious plans** to further improve drinking water quality and acceptability for our customers.

We take our water from a variety of different types of water sources, balancing abstractions across reservoirs, rivers and groundwater sources. Each source poses a different challenge to water quality and acceptability. Our reservoir water is sourced from **upland catchments**, where continued degradation of peatland means that raw water quality is deteriorating and requires increasing levels of treatment. We face the challenge of removing pesticides from water in the large lowland **river catchments** due to agricultural activity. Our **groundwater sources** are impacted by nitrate, primarily from agricultural sources. In a limited number of locations, we face water quality challenges caused by the increasing amounts of algae in river and raw water storage reservoirs. This high algal concentration causes treated water to have an "earthy" taste and smell, which although not harmful, is unacceptable to customers.

Water Treatment Works (WTW) provide mitigation against a wide range of risks and enable us to meet the strict drinking water standards. We have reviewed our current performance and risks and assessed future performance requirements and hazards facing our WTW. We have also assessed the ability of our WTWs to support the delivery of our **Water Resource Management Plan (WRMP),** to ensure we can treat enough water at the right quality in **the long-term**. The WRMP requires us to understand where we currently have seasonal raw water challenges that can require a reduction in flow through the treatment works to protect water quality. Where future risks are inferred by trends in raw water quality deterioration, we have forecast the point at which risks become intolerable. This allows us to **proactively intervene** and informs our long-term planning.

There are also **water quality challenges** to overcome in relation to our **distribution network**. One of the main challenges we face is **discoloured** water caused by a build-up and release of non-harmful material in the pipes. In addition, there is the exposure to **lead** caused by lead pipes, mainly located between the water main and customers' taps. Finally, we are aware of the need for continuing focus on protecting the quality of water stored in service reservoirs. Whilst not part of this submission, we are continuing to invest in the replacement and refurbishment of these assets.

In developing our plan, we have thought about how we impact our customers, Yorkshire's environment and its economy. Considering this, we prefer to **address identified risks by dealing with them at source rather than through increased treatment options**. This approach is advocated in drinking water safety planning and drinking water legislation and regulation.

How have we created our plan?

Our **Drinking Water Safety Plans** (DWSPs) and their underlying data are at the heart of the development of our submission. This approach results in the identification of specific **hazards and risks** which we consider have the potential to result in a risk to drinking water quality or acceptability over a short, medium or long-term period.
We have assessed and projected **raw water deterioration** in Yorkshire, estimating the future date when this would lead to a risk to drinking water quality standards. To address these raw water deterioration risks, **catchment management** remains our **primary strategic approach** and our first-choice intervention. By understanding the timescale to impact we can determine whether catchment, treatment or a combination of both provide the most appropriate solution.

We have worked closely with the EA and other stakeholders in developing our catchment management approach. We will continue to work closely with land owners, land managers and the agricultural sector to protect and enhance the resilience of our raw water sources. This is the first stage in assuring water quality from source to tap. We also have considered the plans set out in our **draft WRMP** to confirm that whilst ensuring customers have **sufficient water** in the future, we do not compromise on the **quality** of water supplied.
Our customers have told us that they are very concerned about **affordability,** both now and into the future. We need to find ways of addressing the pressures faced through deteriorating raw water quality, pesticide usage and the removal of exposure to lead, **without causing customers' bills to become unaffordable.** We need to do this through innovative approaches to ensure efficient, resilient sustainable outcomes.

What does our plan say?

Our forecasts indicate that there are around 60 raw water sources where **catchment** only interventions are the most appropriate to manage the risk of raw water quality deterioration in the medium and long-term. Our catchment programme covers a range of risks to water quality, including colour arising from peat degradation, pesticides, nitrate and saline intrusion on reservoir, river and groundwater sources. We plan to invest circa £9 million in catchment activity to address colour from upland peatland deterioration in the period 2020-2025, along with circa £7 million on reducing the risk of metaldehyde (which is used in agriculture as a slug control product) entering our rivers.

The catchment activity forms part of the Water Industry National Environment Programme (WINEP) which we agree with the Environment Agency (EA). We reference this activity in this submission to ensure visibility of the mitigation of medium and longer-term drinking water safety planning risks.

Metaldehyde remains a significant risk to compliance in supplies drawing from the large lowland rivers of North and East Yorkshire. We do not propose any treatment solutions at our water treatment sites in the period 2020-25, but will continue to work collaboratively with land owners and other stakeholders to manage the risk at source. Our proposed approach includes:

- The provision of resource through Natural England to provide Catchment Sensitive Farming Officers;
- Influencing farming practice;
- Promoting metaldehyde free approaches amongst the supply chain for arable products; and
- Developing a system for the "loan" of equipment to small farms to provide access to new farming technology.

Our review of all the hazards we face leads us to conclude that there are six WTW where we plan to undertake targeted **enhancement of the water treatment process** to assure the **long-term** protection of drinking water quality. These risks arise from a forecast ongoing deterioration in raw water quality over a 10-year+ horizon. These interventions are supported by long-term catchment management proposals within the WINEP to enhance the sustainability of the solution. This enhancement activity is estimated to require £75 million above our ongoing base maintenance costs. We are seeking DWI support for this additional investment to secure long-term drinking water quality.

We propose a **long-term approach** to reduce and eliminate exposure to **lead.** We welcome the opportunity to work closely with the DWI and others to identify the best use of investment in this area of water quality enhancement for the future. In the period 2020-2025, we propose activity to ensure that we reduce the risk of lead exposure to **vulnerable customer groups**. We intend to **reduce the risk of lead exposure in schools and nurseries** across Yorkshire as well as investigations to develop our understanding of the prevalence of lead in the wider population of public buildings. We intend to undertake research and development activity to "extend the length capability of lining" and investigate novel approaches to lead pipe replacement. The overall costs associated with the reduction of lead risk are capped at £15 million.

We also plan to achieve a reduced risk of unacceptability of water to our customers, recognising that the aesthetic reduction in quality undermines our customers' confidence in our service. We intend to continue to reduce the risk of **discoloured water** through the deployment of a range of existing and **innovative techniques** developed to prevent significant re-accumulation of material in the distribution network.

Over the early months of 2018, we will be developing our **Long-term strategy for Water Quality and Acceptability**, which will set out our ambition and approach to reducing risk, and improving resilience and compliance over the next 25 years and beyond.

Our submission has the confidence of both our Board and the Yorkshire Forum for Water Customers. Both have reviewed the preparation of the plan, with visibility of the assurance activities provided by both our independent external auditors, Halcrow, and our own internal **assurance** processes. The Yorkshire Water Board is required to make a Board Assurance Statement for the draft Water Resource Management Plan (WRMP) and final WRMP to confirm the assurance processes and to state that it is satisfied the plan represents the most efficient and sustainable long-term solution. In addition, a statement from the Director of Service Delivery and Director of Asset

Management confirms that the draft WRMP takes account of all statutory drinking water quality obligations, and that the draft WRMP does not plan to fail in meeting drinking water quality legislation.

This submission to the DWI sets out the steps of the long-term plan we intend to deliver in the period 2020-2025. It serves to ensure that our customers continue to get what they prioritise most highly – **a reliable supply of clean, good quality water.**

Contents

Drinking Water Inspectorate Submission Board assurance statement

Our aim is to produce all regulatory submissions in line with the guidance provided.

We believe that good assurance needs to be provided at the right time, proportionate to the level of risk identified, asks the right questions and produces good evidence to support the statements made within the submission. Our assurance approach is risk based and uses a method called 'three lines of assurance'. This is best practice and is described in more detail in our Assurance Plan.

To satisfy ourselves that the information is accurate and accessible, all elements of the report are subject to an appropriate assurance process. In particular, the Board has noted and confirms that:

- Assurance processes follow the company's policy of applying three lines of assurance based upon our annual reporting process which is certified to the British Standard ISO9001 Quality Management System. This is best practice and externally verified;
- The assurance process includes audit checks and challenges by data providers, data managers, senior managers and directors and our external auditors, Halcrow (ch2m). Findings from these assurance processes have been fully reviewed and actions to address any concerns have been implemented, and
- The Board Audit Committee has received the findings from the completed assurance reviews.

The Board of Yorkshire Water understands that it is accountable for the quality and transparency of the information provided within this submission. The Board has reviewed the content of the plan and is supportive of the information as presented. The Board has obtained support from the Board Audit Committee that there are appropriate controls and assurance processes in place regarding the information contained within the submission.

The Board can confirm that the plan takes account of all statutory drinking water quality obligations, and that it does not plan to fail in meeting drinking water quality legislation now and in the long term.

So far as the directors are aware, there is no relevant audit information of which the company's independent technical auditors are unaware. The directors have taken all the steps that they ought to in order to make themselves aware of any relevant audit information and to establish that the Company's independent auditors are aware of the information.

Drinking Water Inspectorate Submission Board Assurance Statement
Signed by Yorkshire Water Services Limited Board of Directors

Anthony Rabin Chairman	**Richard Flint** Chief Executive
Liz Barber Director of Finance, Regulation & Markets	**Pamela Doherty** Director of Service Delivery
Nevil Muncaster Director of Asset Management	**Ray O'Toole** Senior Non-Executive Director
Teresa Robson-Capps Non-Executive Director	**Julia Unwin** Non-Executive Director
Chantal Forrest Company Secretary	**Andrew Wyllie** Non-Executive Director
Michael Osborne Director	**Scott Auty** Director
Andrew Dench Director	

1.0 Introduction

1.1 Structure of this submission

This submission is set out in two parts:
Part A outlines the general approach to our Asset Management Period (AMP) 7 Drinking Water Quality Programme. It sets the context of this submission within our regulatory obligations, demonstrates our engagement with customers and highlights elements of our long-term strategy to improve water quality and acceptability for customers. It also addresses our approach to drinking water safety planning and improving the resilience of our assets. It highlights links to our integrated asset management strategy, for all water supply assets, through our Decision Making Framework (DMF).

Part B provides detailed evidence and our proposals to manage site specific risks to drinking water quality. We have included these where we consider there is a risk of failure which could impact on the quality or acceptability of drinking water that we supply to our customers during AMP7 and beyond. We seek technical support from the DWI to include these proposals in our PR19 business plan submission to Ofwat.

This submission is consistent with our developing long-term strategy as per the September 2017 Guidance Note: "*Long-term planning for the quality of drinking water supplies*". Our long-term strategy will continue to evolve and we are looking to provide details of future interventions in May 2018.

The format of our submission is aligned to the requirements set out in Annex A of the DWI IL 03/2017, its associated guidance note and the PR19 guidance documents published by the EA.

1.2 Summary of submission

Our submission to the Drinking Water Inspectorate is a key component in meeting our customers' priorities. It forms part of the suite of submissions to our regulators, setting out our long-term plans but specifically planning for the period 2020-2025. It describes how we will protect and deliver improved drinking water quality to our customers. Our forecasts indicate that there are 60 water sources where catchment only interventions are the most appropriate to manage the risk of raw water deterioration in the medium and long-term. Our catchment programme covers a range of specific water quality parameters, including colour arising from peat degradation, pesticides, nitrate and saline intrusion on reservoir, river and groundwater sources. We plan to invest circa £9 million in upland catchment activity in the period 2020-2025, along with circa £7 million on reducing the risk of metaldehyde entering our rivers.

There are six WTW where we propose to undertake targeted enhancement of the water treatment process to deliver long-term protection of drinking water quality. These are subject to risks which arise from ongoing deterioration in raw water quality, which we forecast will continue. These interventions are supported by long-term catchment management proposals within the WINEP to enhance the sustainability of the solutions. This enhancement activity is estimated to cost £75 million above our ongoing base maintenance costs. We are seeking DWI support for this additional investment to secure long-term drinking water quality.

We propose a long-term approach to reduce and eliminate exposure to lead. In the period 2020-2025, we propose activity to ensure that we reduce the risk of lead exposure to vulnerable customer groups, including those requiring continuous supplies and those registered for home dialysis. We also propose targeted activity to reduce exposure to lead in schools and nurseries across Yorkshire. We intend to undertake research and development activity to "extend the length capability of lining" and investigate novel approaches to lead pipe replacement. The overall costs associated with the removal of lead risk are capped at £15 million.

We also plan to achieve a reduced risk of unacceptability of water to our customers, recognising that the aesthetic reduction in quality undermines our customer's confidence in our service. We intend to continue to reduce the risk of discoloured water through the deployment of a range of existing and innovative techniques to prevent significant re-accumulation of material in the distribution network.

Our proposed programme of investment, for which we seek DWI support, is outlined in Table 1 below. Our programme includes seven schemes to mitigate the risk of drinking water quality failures and improve the acceptability of water to customers. It does not represent our full investment proposals to ensure long-term protection of drinking water quality and acceptability in AMP7.

Table 1: Overview of proposed Totex improvements of Drinking Water Quality (for which we seek DWI support).

Scheme Name	Driver	Capex (£m)	Opex (£m/yr)	Best Technical Solution	Manages risk to customers	Lowest WLC
Lead (Regional)	Lead risk reduction	15.0	0.0	Y	Y	Y
Tophill Low WTW	*Cryptosporidium;* taste & odour	16.3	0.4	Y	Y	N
Chellow WTW	Colour (DBPs); run to waste; turbidity	23.9	1.1	Y	Y	N
Embsay WTW	Colour (DBPs); turbidity, manganese	8.0	0.1	Y	Y	Y
Fixby WTW	Colour (DBPs); turbidity	5.6	0.04	Y	Y	Y
Sladen WTW	Colour (DBPs); run to waste; turbidity	14.6	0.2	Y	Y	N
Oldfield WTW	Colour (DBPs); turbidity	6.1	0.1	Y	Y	N
Total		89.5	1.9			

1.3 Regulatory framework

In the lead-up to our DWI submission, Defra and our regulators have published a series of guidance documents. In summary, these set out expectations to secure the long-term resilience of water supplies in the face of climate change and an increasing population. The focus has been on environmental protection and innovation.

In 'Creating a great place for living: Enabling resilience in the water sector', published in March 2016, Defra noted that climate change, through changing weather patterns, such as higher summer temperatures and lower summer rainfall, and population growth, pose long-term challenges on the water sector in England. This is because both impact on the balance of water supply and customer demand. They also impact on upland water quality and the timing of impacts of drinking water pollutants such as colour, metaldehyde and nitrate.

The Defra document set out a policy road map to adapt to climate change which has continued through the 2017 UK Climate Change Risk Assessment. We anticipate the 2018 National Adaptation Programme will encourage further coordinated activity.

In tandem, Ofwat has evolved its regulatory framework in line with its new duty to further the long-term resilience of the water sector. This focusses consideration of the long-term challenges posed by climate change, population growth and changes in consumer behaviour.

Defra published 'The government's strategic priorities and objectives for Ofwat' in September 2017. It set out Defra's priorities for Ofwat and the water industry and highlighted two overarching priorities:

- Securing long-term resilience: Customers expect resilient services, now and in the future – but some regions are exposed to substantial risks from service failures, for example due to drought.
- Protecting customers: Every home and business depends on a resilient water industry – but not everyone can afford their water bill.

The document included a third priority: Ofwat should promote markets to drive innovation and achieve efficiencies in a way that takes account of the need to further: (i) the long-term resilience of water and wastewater systems and services; and / or (ii) the protection of vulnerable customers.

The DWI published the following documents to inform the price review:

- DWI Information Letter 03/2017 'Update to guidance documents, including guidance note on long-term planning for drinking water quality', September 2017.
- 'Guidance on implementing the Water Supply (Water Quality) Regulations', 2016.
- 'Guidance Note: Long-term planning for the quality of drinking water supplies', September 2017.

The final EA and Natural England 'Water industry strategic environmental requirements (WISER) Strategic steer to water companies on the environment, resilience and flood risk for business planning purposes' was published in October 2017. It set out the obligations, expectations and best practice for the water industry, including Drinking

Water Protected Areas. In summary, the EA and Natural England support catchment measures to prevent deterioration in water quality and reduce the need for additional treatment.
The WISER document was supported by other EA guidance documents, notably:

- 'PR19 Driver Guidance Driver Name: Drinking Water Protected Areas (DrWPA)' Feb 2017.
- 'Supplementary PR19 Driver Guidance to Drinking Water Protected Areas: Principles for developing the metaldehyde measures for the Water Industry National Environment Programme (WINEP) for PR19' May 2017.
- 'PR19 WINEP and Drinking Water Protected Areas: An update to the Agency's position on metaldehyde and ongoing catchment measure's' August 2017.
- 'Including catchment management measures in the PR19 Water Industry National Environment Programme' October 2017.

In developing our submission, we have reviewed these and other relevant documents to arrive at a water quality programme which meets the needs of our regulators and the customers, businesses and environment of Yorkshire. It mitigates risks to drinking water safety and provides our customers with what they have identified as their number one priority – a reliable supply of clean, good quality water.

Our programme is also framed within the context of our developing long-term strategy for water quality, acceptability and resources. Our submission has the confidence of both our Board and the Yorkshire Forum for Water Customers. Both have reviewed the preparation of the plan, the assurance provided by independent external auditors, Halcrow, and other internal assurance processes. In addition, a signed statement from the Director of Service Delivery and Director of Asset Management confirms that the draft Water Resource Management Plan, submitted to Defra in December 2017, does not plan to fail in meeting drinking water quality legislation.

1.4 Risk-based approach

1.4.1 Drinking water safety planning - approach

Our approach to drinking water safety planning is in line with that of the DWI guidance document (A brief guide to drinking water safety plans) and follows the steps shown below (Figure 1).

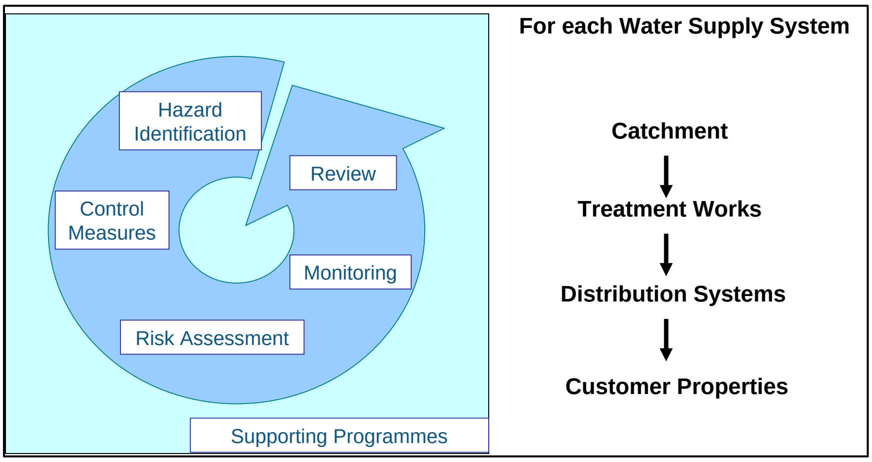


Figure. 1: Drinking Water Safety Plan approach.

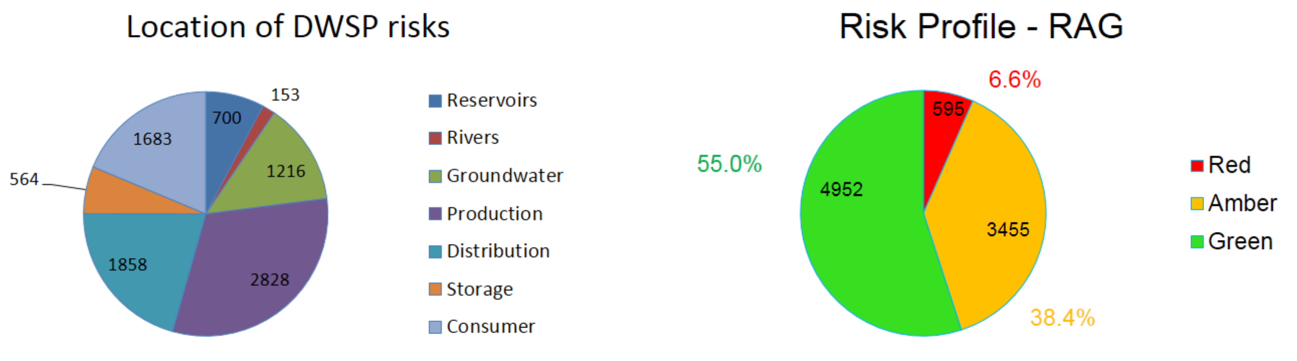
1.4.2 DWSP risk assessment cycle

Our DWSPs and their underlying data are at the heart of the development of our submission. Our drinking water safety planning process is a holistic and consistent approach to the assessment of hazards to water quality from catchment to tap and incorporates our Distribution Operation and Maintenance Strategy (DOMS). This approach is subject to our continual review process (as shown in Figure 1 above and table 2 below) which identifies intolerable risks. We define intolerable risks as those residual risks which are potentially harmful to human health and which cannot be mitigated through sustainable company operations. The reviews consider short, medium and long-term control measures to reflect the time it takes for mitigation to have an impact on the hazard in terms of risk reduction.

Table 2: Description of short, medium and long-term control measures.

Measure	Description
Short-term	Generally implemented as part of the routine operations for the Company. Examples would include changes to procedures, operating conditions and routine flushing activity. Control measures would not be expected to improve the mitigation of risk over a period exceeding 1 year.
Medium-term	Likely to be implemented and monitored over several years, generally within an AMP. Control measures are likely to involve more profound changes to the control of processes, catchment investigation and engagement, or systematic flushing.
Long-term	Likely to be implemented over one or more AMP. Usually driven by long-term trends of deterioration in raw water quality, by which a future risk can be inferred for the supply. Control measures would typically involve the building of new processes, the development of new sources and WTW, major truck main refurbishment schemes, and catchment management mitigation. These control measures have differing degrees of uncertainty in terms of the speed of delivery, effectiveness in delivering the outcome and the time required for the control measure to reduce the impact of the hazard.

The risk position used within this submission is consistent with our November 2017 monthly submission to the DWI under Regulation 28. We have cross-referenced our proposals to the relevant Risk IDs used in our monthly Regulation 28 reports. Risks to drinking water quality and acceptability forecast to be realised before 2028 are covered by this submission. Risks to quality and acceptability that are unlikely to be realised before 2028 have been included in the EA's WINEP, as catchment management schemes.



Stage	No. of Red Risks	No. of Amber Risks	Key Red Risk hazards
Reservoirs	135	159	Colour, Manganese, Iron
Rivers	46	47	Pesticides, Crypto, Manganese, Bacteria
Groundwater	87	371	Nitrate, Crypto, Bacteria, Turbidity
Production	60	1179	Bacteria, Crypto, DBP's, Nitrate, Metaldehyde
Distribution	6	801	Discolouration (trunk mains), No Supply
Storage	6	235	Bacteria
Consumer	255	663	Bacteria, Chemical, Lead

Figure. 2: DWSP identified risk position (November 2017).

Figure 2 shows the total risk position identified through our drinking water safety planning processes. As part of our governance and assurance process, this risk view is reviewed quarterly by Directors of Asset Management and Service Delivery, who sign off our DWSPs.

Table 3: DWSP change in risk position for WTWs associated with this submission.

Stage	No. of Red Risks	No. of Amber Risks	Key Red Risk hazards
Reservoirs	135	159	Colour, Manganese, Iron
Rivers	46	47	Pesticides, Crypto, Manganese, Bacteria
Groundw ater	87	371	Nitrate, Crypto, Bacteria, Turbidity
Production	48 (-12)	1119 (-60)	Bacteria, Crypto, DBP's, Nitrate, Metaldehyde
Distribution	6	801	Discolouration (trunk mains), No Supply
Storage	6	235	Bacteria
Consumer	255	663	Bacteria, Chemical, Lead

Table 3 demonstrates the reduction in risk position achieved through the delivery of the WTW interventions detailed in Part B of this submission.

Having identified risks, we identify mitigation. If the mitigation identified and implemented, is considered acceptable and sustainable only in the short-term, then longer-term mitigation is identified. Our long-term mitigations are typically delivered over multiple AMP periods and are developed within our Periodic Review Submission process. This Asset Management process (associated with DWSPs) is shown in Figure 3.

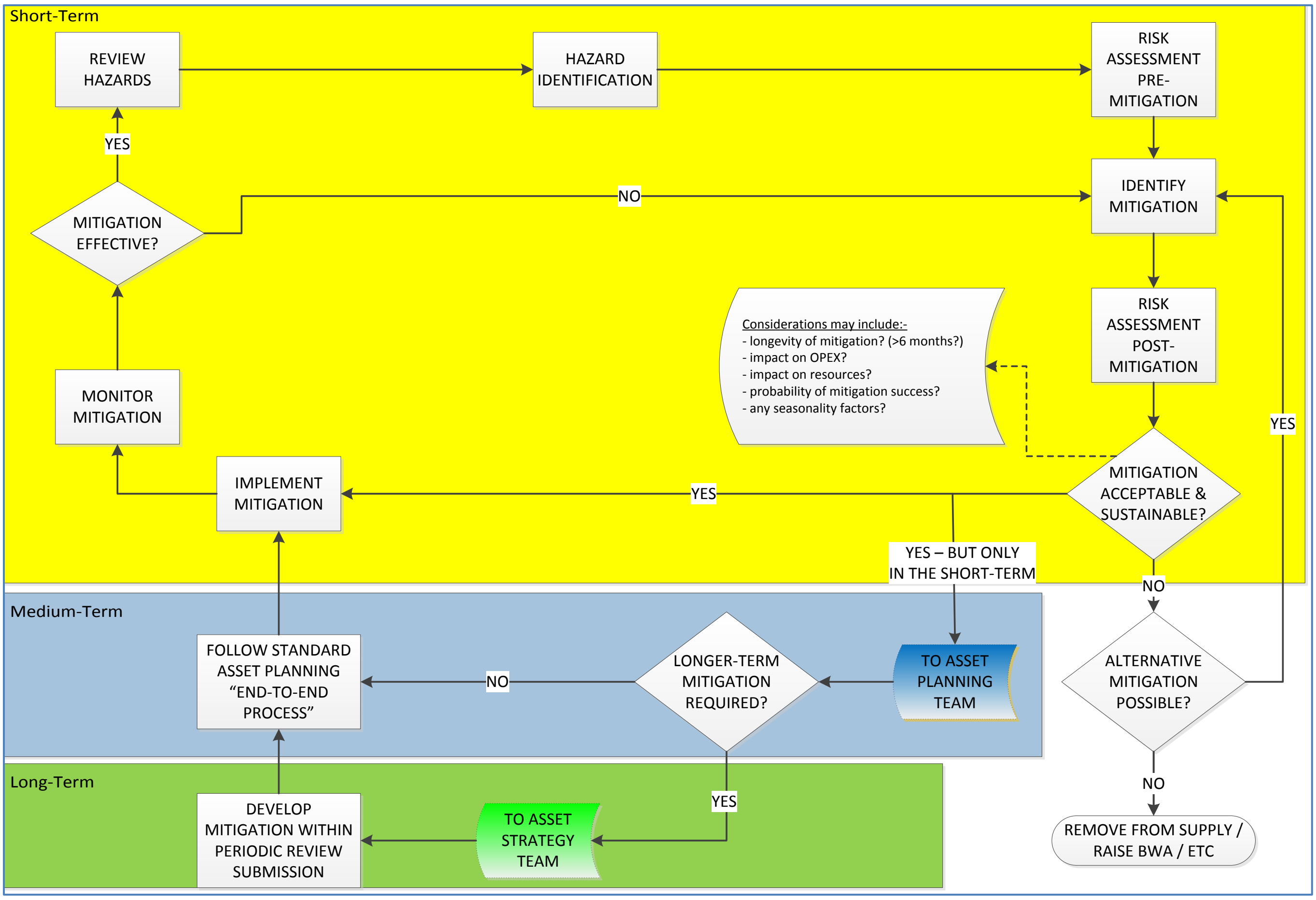


Figure. 3: Process for development of measures following hazard identification.

The proposals for which we seek DWI support in this submission are associated with the long-term loop in Figure 3 and represent significant interventions, beyond the scope of the Company’s short-term asset management process. These interventions are developed for inclusion in the Periodic Review submission through the use of the DMF which encompasses, the system and tools we use to support decision making.

1.4.3 Decision Making Framework

The DMF is an innovative development of our approach to totex investment planning. DMF is made up of four key elements: people, process, governance and systems. It is the framework by which we make risk-based decisions. It is built around a new “Service Measure Framework” which puts customers at the heart of our decision making by providing a common definition and a valuation of service. Our choices in decision making are based on the overall benefit delivered by an intervention. Our approach to understanding the benefit of solutions has been broadened to consider the six capitals (see Figure 4), for example, the consideration of natural and social capital ensures our decisions are resilient and sustainable.

1.4.3.1 Understanding service risk through the application of the Service Measure Framework

We start by expressing risk to service through both modelled and non-modelled approaches. The approach formalises our risk methodology and ensures that all service impacts are stored and scored in a consistent manner.

Risk is expressed as Service impacts based on the following factors (as set out in Figure 4):

- Frequency of event (for example, asset failure or raw water outside of design envelope)
- Probability of service impact.
- Severity of the impact.

  Quantity or scale of the impact.

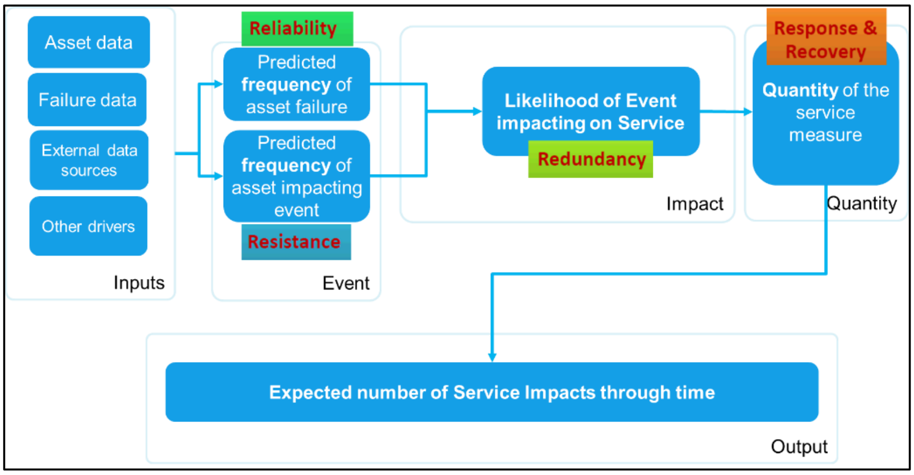


Figure. 4: Risk expression in the Decision Making Framework.

The risk to service of asset failure is modelled by collecting and analysing data on both above and below ground assets. The asset failure distributions used are generic for asset types, but are made asset specific through the analysis of performance data (for example, historic failures of assets).

Other non-asset failure related risks (such as power or weather-related failures) are identified through a variety of investigations and through existing risk management approaches, such as DWSPs, as part of our approach to resilience in the round. The data collected allows us to identify the expected service impacts of failure events through time. As a result, we are able to estimate current and future service levels.

These risks are entered into DMF with multiple solutions attached, allowing optimisation to take place for effective asset management.

1.4.3.2 Quantifying cost

We apply a totex approach to risk resolution, creating a programme with the optimum balance of capex and opex to drive service risk improvement. We estimate the costs of capital solutions using unit cost models developed within our unit cost database (UCD). These costs fully reflect our current procurement methods and the efficiencies and synergies being delivered in AMP6. Opex costs are derived from components based on historic costs, such as maintenance, energy, chemicals and people. The capex and opex costs are combined in DMF, which allows optimisation based on whole life cost.

1.4.3.3 Quantifying wider benefit

We have enhanced our approach to understanding the benefit of our solutions, aligning our approach to six capitals (see Figure 5). Rather than just valuing customer willingness to pay and financial benefits to Yorkshire Water, we are now looking at the wider benefits of our investment decisions, including their impact on the environment (natural capital), people (human capital) and society as a while (social capital).

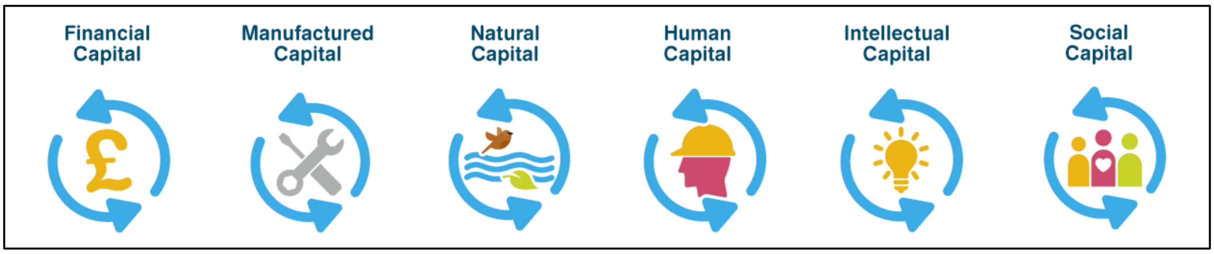


Figure. 5: The six capitals.

Where there is sufficient confidence to do so, we have mapped a change in each service measure to one or more of the six capitals to obtain a monetary unit rate.

The approach helps us understand the impact of existing asset failures and the benefit we retain by fixing them, as well as the ability to evaluate more creative long-term, resilient solutions. We are applying it as a framework across our whole investment programme, not just as an assessment on individual schemes.

2.0 Current and future performance

2.1 Performance in AMP6

In AMP6 to date we have improved both our compliance with drinking water standards and customer acceptability measures. We have achieved this through targeted improvement schemes and the placement of additional operational controls on our catchments, treatment facilities, water storage and pipe networks. At this stage in the AMP, some of the improvement programmes that we agreed for AMP6 have been delivered and have resulted in improved water quality to the customers served. The more significant schemes are due to be delivered over the next 2 years, further enhancing water quality for our customers.

We have demonstrated our continued improvement in the delivery of drinking water quality using the old and new measures in Table 3. At the simplest level, the number of breaches of water quality standards has reduced year on year. Based on the Overall Failure Index (OFI), our AMP6 KPI, we have demonstrated improved performance. Considering the DWI Yorkshire Compliance Risk Index (CRI), and noting that the 2015 figure contained a calculation anomaly for iron, we are making significant progress.

Table 4: Water Quality Performance in AMP6 by measure.

	2014	2015	2016
Industry Compliance Risk Index			4.78
YKS Compliance Risk Index	5.392	6.221	3.836
YKS Mean Zonal Compliance	99.954	99.954	99.960
YKS Overall Failure Index	99.942	99.958	99.971
No of fails	119	85	79

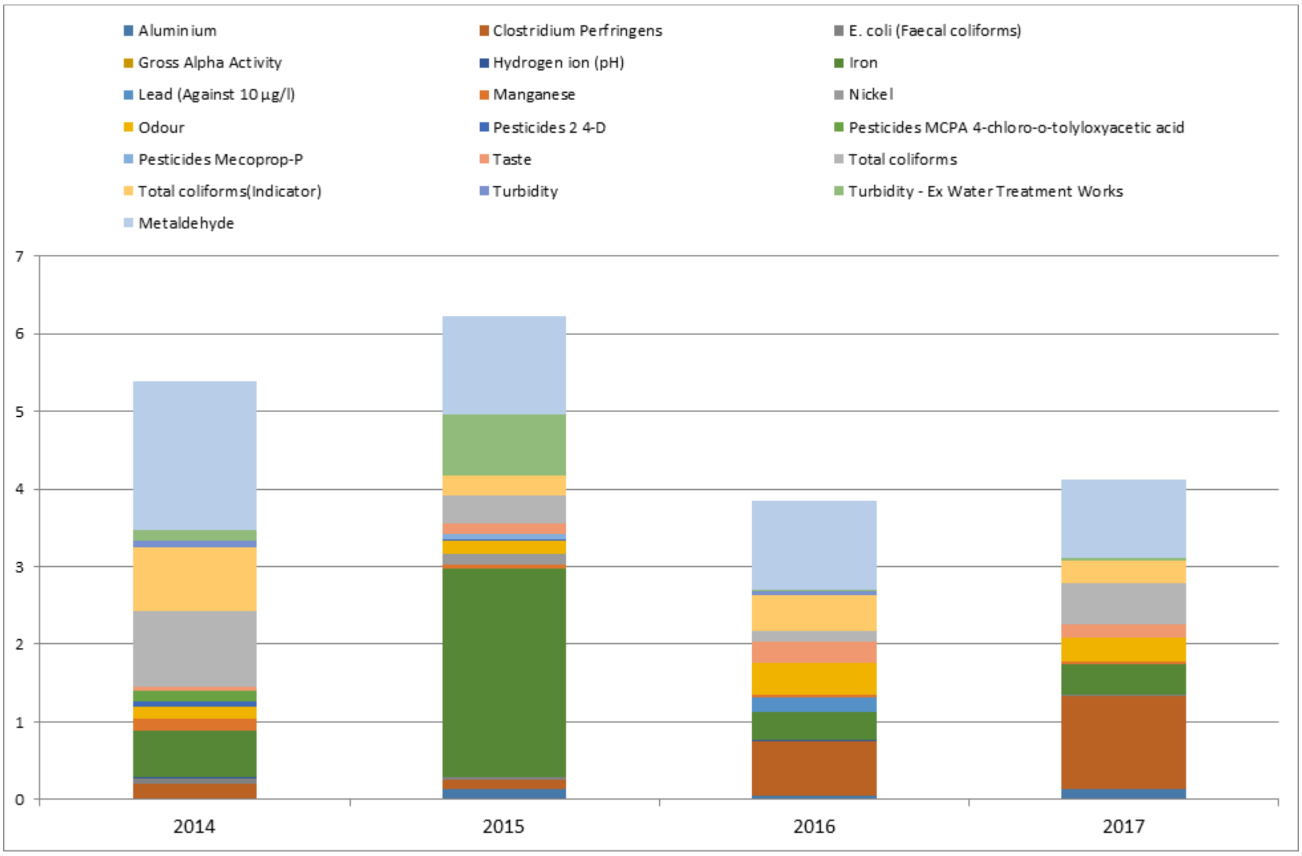


Figure. 6: Water quality performance AMP6 by parameter percentage contribution to Compliance Risk Index.

The parameters contributing to CRI impact can be seen for the last three years in Figure 6 above. In each of the years (assuming 2015 iron contribution is reset) the largest single contribution to non-compliance is metaldehyde. This occurs at our large river derived sources, where the metaldehyde standard is exceeded. Although progress has been made in reducing the risk across the region, significant catchment activity continues and will be enhanced to reduce the risk to compliance.

Other significant contributors are:

- Total coliform bacteria - in many cases found due to the condition of customers' taps,
- Iron – due to the presence of un-lined cast iron in our network, and
- Taste and odour – due to a range of causes, for example, algae.

There are no exceedances included for disinfection by-products (DBPs), for example, trihalomethanes (THMs) where the standard is 100µg/l and around which most of the programme in this document is focused. This is due to the imperative to keep these compounds "as low as possible", as laid out in Regulation 26 of Water Supply (Water Quality) Regulations, 2016. We therefore aim to address this risk before compliance becomes an issue by predicting deterioration within DWSPs, and by reference to the DWI 50µg/l annual average criterion for samples taken in Water Supply Zones (WSZs). We generally look to drive interventions when the WSZ average is consistently in the 45-50µg/l range and the raw water hazard driving the risk is not yet able to be controlled by other means.

2.2 Long-term strategy overview

This section describes our approach to developing our long-term strategy for drinking water quality, acceptability and resources. It serves to provide a summary of the work to date and will be supplemented with the submission of the full and detailed strategy to the DWI in May 2018, as set out in 'Guidance Note: Long-term planning for the quality of drinking water supplies' September 2017.

2.2.1 Developing our strategy with our customers

Yorkshire Water is developing a long-term water strategy which focuses on water quality and acceptability as well as water resources. The submission to the Drinking Water Inspectorate and the Draft Water Resource Management Plan have been developed in accordance with the early years of this strategy. The strategy is fundamentally based on outcomes that were developed with customers, derived from what they told us was important to them:

- We provide you with water that is clean and safe to drink
- We make sure that you always have enough water

These outcomes were developed with customers, five years ago and over recent years, we have had nearly 19,000 customer conversations across a wide variety of formats. The conversations have helped us understand more about what is important to our customers now and in the future. We have talked to our customers about how water plays a part in their lives and the dependencies we all have on water.

Our customers have clearly told us that their number one priority is still a reliable supply of clean, good quality, water. They need to know that their water supply is secure, wholesome and sustainable, but they want us to deliver this in different ways. This means we must change the way we work to meet our customer's expectations. The developing long-term strategy for water supply will take account of customer's expectations of us.

Our customers want us to stop failures in service from affecting their lives. For this reason, we need to ensure that our water supply system is resilient and sustainable, and can deliver both the quantity and quality requirements. We will take less from the environment and maximise use of the water that is abstracted. We will ensure we take action to tackle losses and the wasting of water in every way, and we will do this in a way that does not compromise water quality or acceptability, allowing us to improve our performance in this area.

2.2.2 Future challenges

We need to be mindful of future challenges and the impact they have on drinking water quality, acceptability and resources. The table below summaries the key future challenges and shows how they impact on our water supply.

Table 5: Key future challenges and impacts on water supply.

	Impacts on:		
	Quality	Acceptability	Quantity
Population growth			•
Growing economy			•
Climate change	•	•	•
Changing weather patterns	•	•	•
Environmental protection	•		•
Agriculture & land use	•	•	•
Asset deterioration	•	•	•

We take our raw water from a variety of different types of water supply, balancing across reservoirs, rivers and groundwater sources. Each source poses a different challenge to quality and acceptability. There are also water quality and acceptability challenges to be overcome in relation to treatment and the water distribution network. For each of our water sources and our distribution network, we have identified current and future impacts on quality and acceptability.

Table 6: Potential water quality and acceptability impacts on raw water (by water source); treatment and distribution.

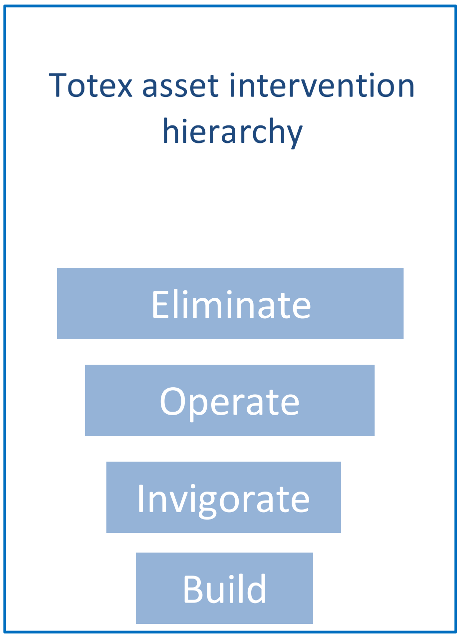
Impact	Raw water			Treated Water		
	Ground	River	Reservoir	Treatment	Distribution	Customer
Saline intrusion	•			•		
Nitrate	•	•		•		
Pesticides	•	•	•	•		
Colour		•	•	•		
Asset failure	•			•	•	
Micro-organism	•	•	•	•	•	•
Pipe material					•	•
Tap material						•
Lead						•

2.2.3 Our response – quality, resilience and sustainability

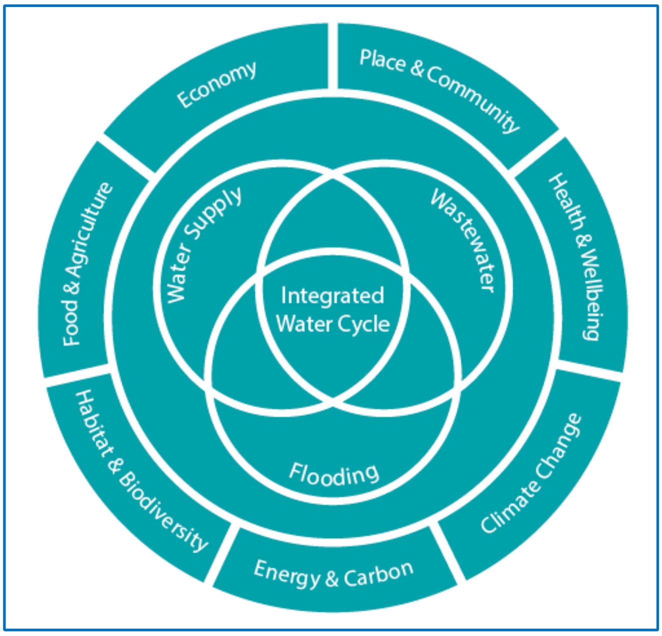
In the development of our long-term strategy for the whole company, we have thought about how we impact our customers, Yorkshire's environment and its economy. The need to abstract more water in the future could impact on our environment. We use chemicals and electricity to treat and deliver water to the homes and businesses of

Yorkshire. As the population grows, we will need to use more of these resources to guarantee high quality and acceptable water – unless we start to do things differently.

Considering this, our strategic imperative is to address current and future risks by dealing with them at source rather than through ever-increasing treatment options. Our response is to apply the Totex Asset Intervention Hierarchy (Figure 7). The Totex Asset Intervention Hierarchy is key to developing a long-term resilient plan, and also to ensuring the use of the least carbon and most affordable solutions. We seek a multi-stakeholder multi-benefit solution approach, where risks are addressed collaboratively by a group of stakeholders, who then share in a broader suite of benefits. This approach is directly applicable to catchment management interventions.



6a Totex asset intervention hierarchy



6b Multi-stakeholder multi-benefit principle

Figure. 7: Totex Asset Intervention Hierarchy and multi stakeholder multi benefit approach.

The application of the principles of the totex asset intervention hierarchy (Figure 6a) support our resilience objectives. The principle is that if a risk can be eliminated at source, this is the most sustainable approach – for example, catchment management interventions to improve the peatland and reduce colour in raw water. Operate and invigorate principles are about using the existing assets to best effect through changing operational practice or taking advantage of process headroom or using resources more efficiently. The final principle is build – if a risk cannot be mitigated through elimination, or the operation or invigoration of existing assets, then a build solution is delivered. Application of the eliminate, operate and invigorate principles should be applied even if a build solution is delivered as this will minimise the size of the build and ensure it is fit as a long-term solution (for example, the twin track approach to treatment and catchment management interventions).

Figure 6b represents the approach to multi-stakeholder, multi-benefit solutions. It shows that through bringing stakeholders together around the integrated water cycle, a broad set of benefits can be achieved. Recognising the broader set of benefits, for example, from economy; community and place to habitat and biodiversity, can also facilitate the involvement of a broader group of stakeholders.

The implications of adopting these approaches in our water supply strategy and our submission to the DWI plan are that:

- Catchment interventions are a first choice (Eliminate: multi-stakeholder multi-benefit solutions).
- We promote sustainable long-term solutions for current and future generations, delivered at the most appropriate time.
- Drinking Water Quality is always central to decision making on related matters (for example, in water resource management planning).
- Resilience is increased through a reduction in asset failures and where failures occur, the service impact is mitigated (Operate and Invigorate).

2.2.3.1 Resilience and innovation

Introduction

Resilience is a key theme of our PR19 business plan, because ensuring that our services are resilient is a vital part of excellent customer service. We know that our customers worry about the future availability, security and cost of water, and about the risk of flooding. In addition, as Ofwat note "…the nature, awareness of and tolerance to future threats is changing. As a result, resilience has moved up the political and social agenda."

We have adopted the resilience definition from the Ofwat Task and Finish Group: ''Resilience is the ability to cope with, and recover from, disruption and anticipate trends and variability in order to maintain services for people and protect the natural environment now and in the future."

Our response is to take a 'whole business resilience' approach and consider both acute shocks, such as extreme weather events, and chronic stresses, such as climate change and population growth. This submission focuses primarily on operational resilience activity.

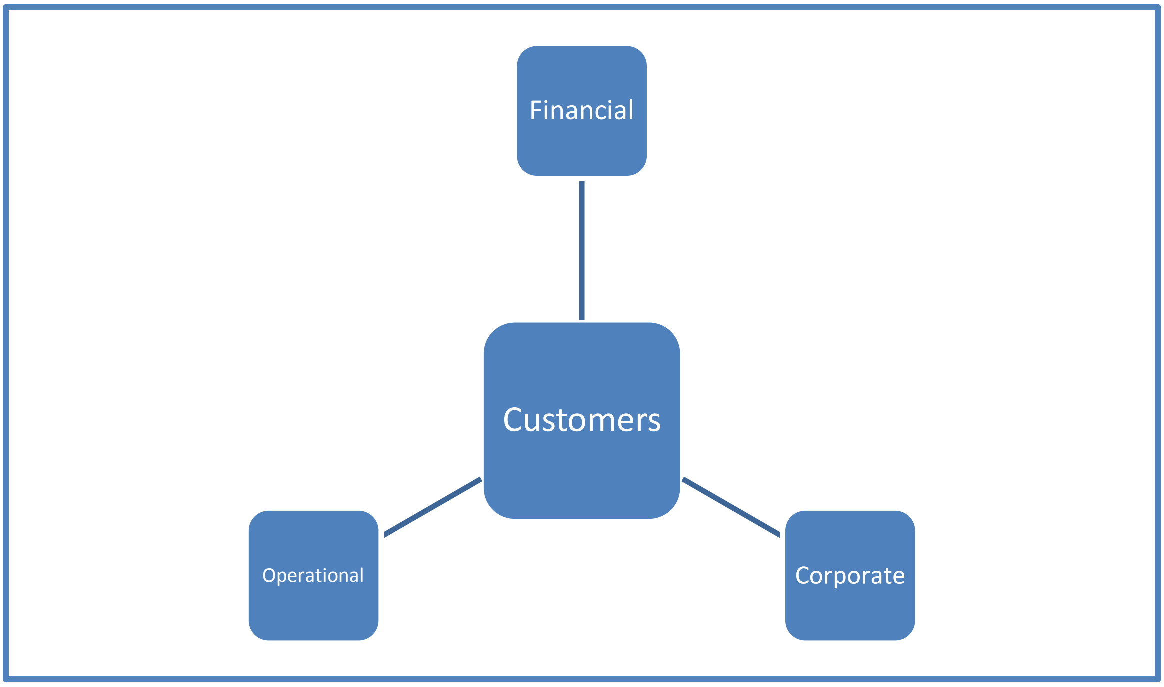


Figure. 8: Components of whole business resilience.

Our approach to resilience follows the widely adopted Cabinet Office resilience guide 'Keeping the country running' and subsequent guidance.

Figure. 9: The components of infrastructure resilience - In building resilience, the contribution made by each of these four components needs to be considered.

The resilience challenges

In the lead-up to our DWI submission, Defra and our regulators have published a series of guidance documents. In summary, these set out expectations to secure the long-term resilience of water supplies in the face of climate change and an increasing population.

In 'Creating a great place for living: Enabling resilience in the water sector', published in March 2016, Defra noted that climate change, through changing weather patterns such as higher summer temperatures and lower summer rainfall, and population growth pose long-term challenges on the water sector in England. The Defra document set out a policy road map to adapt to climate change which has continued through the 2017 UK Climate Change Risk Assessment and we anticipate the 2018 National Adaptation Programme will encourage coordinated activity. Defra published 'The government's strategic priorities and objectives for Ofwat' in September 2017.

It set out Defra's priorities for Ofwat and the water industry and highlighted two overarching priorities:

- Securing long-term resilience: Customers expect resilient services, now and in the future – but some regions are exposed to substantial risks from service failures, for example due to drought.
- Protecting customers: Every home and business depends on a resilient water industry – but not everyone can afford their water bill.

The document included a third priority: Ofwat should promote markets to drive innovation and achieve efficiencies in a way that takes account of the need to further: (i) the long-term resilience of water and wastewater systems and services; and / or (ii) the protection of vulnerable customers.

Our 'Climate Change Strategy – Enhancing resilience to weather and reducing carbon emissions', 2013[1], identified the main water quality climate change risks we see from the changing climate and more variable weather. Our response 'Adapting to a changing climate Yorkshire Water's Adaptation Report', 2015[2], summarised our response to a changing climate and our mitigating actions in the period to 2020. This work has informed our approach to resilience, particularly catchment management and the throughput of each WTW to deliver our WRMP.

Climate and land use risk informed the supporting work for this submission to DWI and the also the draft WRMP submitted to Defra. Climate and weather have been considered alongside land use risks to determine medium to long-term catchment resilience, described in the rest of sections 2, 3 and 4. The water quality trends and predictions were also used to inform a review of what our treatment works can deliver, and what we require of them in the future. We have identified key actions which we are developing further, that will allow us to more reliably and resiliently deliver water production.

[1] https://www.yorkshirewater.com/sites/default/files/downloads/Climate%20Change%20and%20Weather%20Resilience%20at%20YW%20July%202012.pdf

[2] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/474358/climate-adrep-yorkshire-water.pdf

The resilience imperative

The way we work needs to be informed by new ideas, best practice and challenge. We cannot rely on just using the types of approaches we have used over the last 25 years to deliver good quality drinking water. Up to the current AMP we have largely relied on building WTW and other infrastructure to deliver drinking water quality. This was the right thing to do and involved many innovations to drive down cost and improve service to the levels we see today. The infrastructure will continue to play a key role in effectively and reliably mitigating DWSP risk. When we consider the challenges such as changing weather and increasing population, these methods will become increasingly costly – both financially and in terms of environmental impact. For some of the challenges we are considering innovative ways of doing things that will deliver great service, resilience and value for money with less impact on the environment and more additional benefits to customers, communities and the environment.

Risk management is at the heart of our drinking water safety planning for the current and previous business plan. For the PR19 Drinking Water Quality submission we have further integrated DWSP into business processes and undertaken a richer longer-term review of risk. We have applied our totex hierarchy approach described below to solution optioneering. In particular, we have looked at the natural and artificial catchments of our sources described in section 3 to understand their complexity and evaluate the potential of catchment solutions. This puts the natural environment at the core of water service delivery to help deliver long-term, best value and resilience. Conversely, poorly managed catchments will erode our resilience and lead to increasing risks.

Resilience innovation

One example of where we have been working to improve the resilience of the natural environment is in upland management. By working collaboratively with farmers and other land managers, and through our funding of projects jointly with other water companies and partners, we have driven change in the way that the uplands are managed. This helps us to protect water quality at source, improve resilience and minimise treatment costs. However, the benefits are wider than simply water quality. Restored uplands can also store more water to help to reduce flood risk, mitigate climate change by storing carbon, improve biodiversity and provide areas for recreation.

AMP7 catchment resilience

In AMP7 we are planning to invest significantly more in catchment management and catchment resilience. To date our upland catchment management has focused on restoring past damage and preventing further damage taking place. Our AMP7 plan is more ambitious, as we will seek to restore active peat formation to achieve functioning ecosystems.

Over AMP6 we have evaluated the potential effectiveness and technical approach to catchment management for metaldehyde and nitrate. In AMP7 we are substantially upscaling catchment management for metaldehyde and deploying catchment management for nitrate for the first time.

We have taken our learning from collaboration in the uplands, and are now applying this to improving lowland catchments. Collaboration helps deliver:

- Better value - speeding up research,
- The practical delivery of research findings,

- Cultural change and engagement,
- The deployment of innovation and
- Increased capacity in the supply chain.

For this reason, it is a major element of our approach to catchment management.

"Yorkshire Wildlife Trust and the Yorkshire Peat Partnership welcome Yorkshire Water's long-term planning approach to providing affordable drinking water. On Yorkshire's iconic moorland landscape, direct funding by Yorkshire Water to restore upland blanket bog links into wider plans to improve the resilience of upland water catchments facing the challenges of climate change and changing land-use. The rewetting of blanket bog, in particular, restores one of Britain's largest semi-natural landscapes and one of the world's rarest ecosystem types. It ensures the mournful whistle of golden plover, the bubbling of curlew, the glitter of carnivorous sundew or the multi-coloured carpet of Sphagnum mosses remain part of that moorland scene. The by-product is the restoration of the ecosystem services that these blanket bogs provide – reduced flood peaks protecting millions of people downstream of the moors from the dreadful effects of flooding; less colour in raw water ensuring drinking water remains affordable; and open space to enjoy healthy outdoor exercise. These are the win-win-wins that lie at the heart of Yorkshire Water's approach."

Rob Stoneman, Chief executive, Yorkshire Wildlife Trust

THE wildlife TRUSTS Yorkshire Wildlife Trust

Yorkshire Peat Partnership

We are funding Catchment Sensitive Farming officers within Natural England, to work with the agricultural sector to reduce pesticide and fertiliser use, and to enhance soil health.

We will broaden and deepen our commitment to catchment management over the next five years and beyond, extending our work with agriculture in lowland catchments whilst continuing to restore degraded upland habitats. This is described further in section 3.

Operational resilience

We have identified key actions which will allow us to deliver more reliable and resilient water production. This is focused on the key areas of maintenance and the prevention of and recovery from equipment failure to improve reliability, including:

- Good practice in maintaining assets, in particular for dosing systems and monitoring and control systems.
- Pro-active preventative replacement strategies and / or fail-safe back up facilities to reduce risk.

- Improved reliability and use of on-line monitoring systems to improve responsiveness.
- Developing a plan to retro-fit run to waste systems on all WTW.

To achieve these challenging internal targets, will require us to review our processes, including maintenance; control room alarm handling; incident response; promotion; planning and scheduling of work, as well as water resource allocation planning and water quality procedures and processes. In order to build our resilience further, we will take a predictive and proactive approach to Water Treatment Works maintenance; improving asset stability, reducing down-time and increasing asset availability. This will be supported by trials of a new operating model at five of our critical sites, where there will be additional focus on availability and process safety.

In developing our long-term approach to resilience, we have undertaken criticality assessments for 17 sites and water supply systems which were identified as presenting the greatest risk to the key service elements of water quality and availability. Vulnerability assessments have been completed to allow the ranking of these sites to prioritise interventions.

Water Supply System Resilience Dashboards have been created to allow ease of review and interrogation of outputs. Thresholds and descriptors have been set up within the dashboard, which can be modified to reflect any current or future agreed standards or strategic principles. The dashboard view allows quick and easy identification of any current and future shortfalls, and a risk-based approach to delivering resilient services in the long-term.

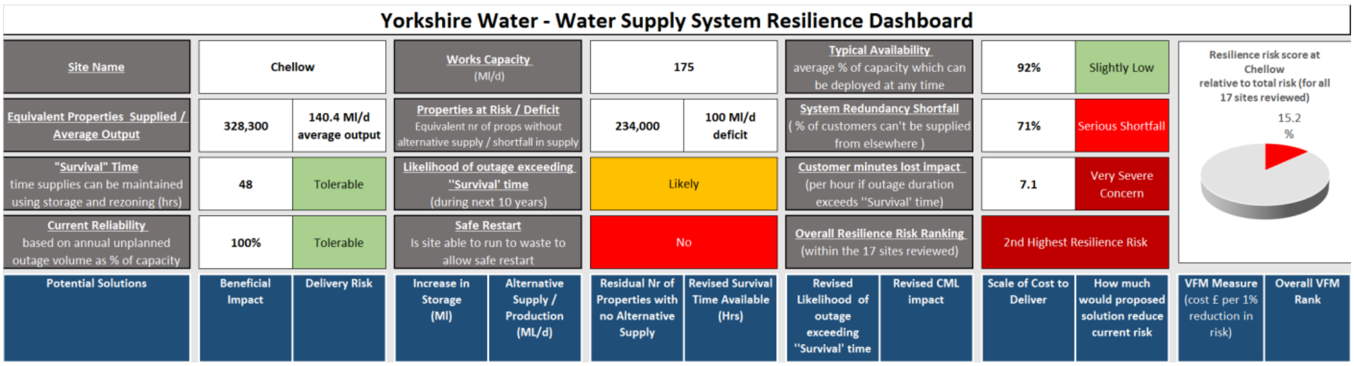


Figure. 10: Example Water Supply System Resilience Dashboard.

Potential solutions to resilience shortfalls are displayed on a source to tap schematic which allows the visualisation of potential connectivity within and between water supply systems. These are then able to be compared for the system under consideration, and across all systems to identify an optimal approach to enhancing resilience.

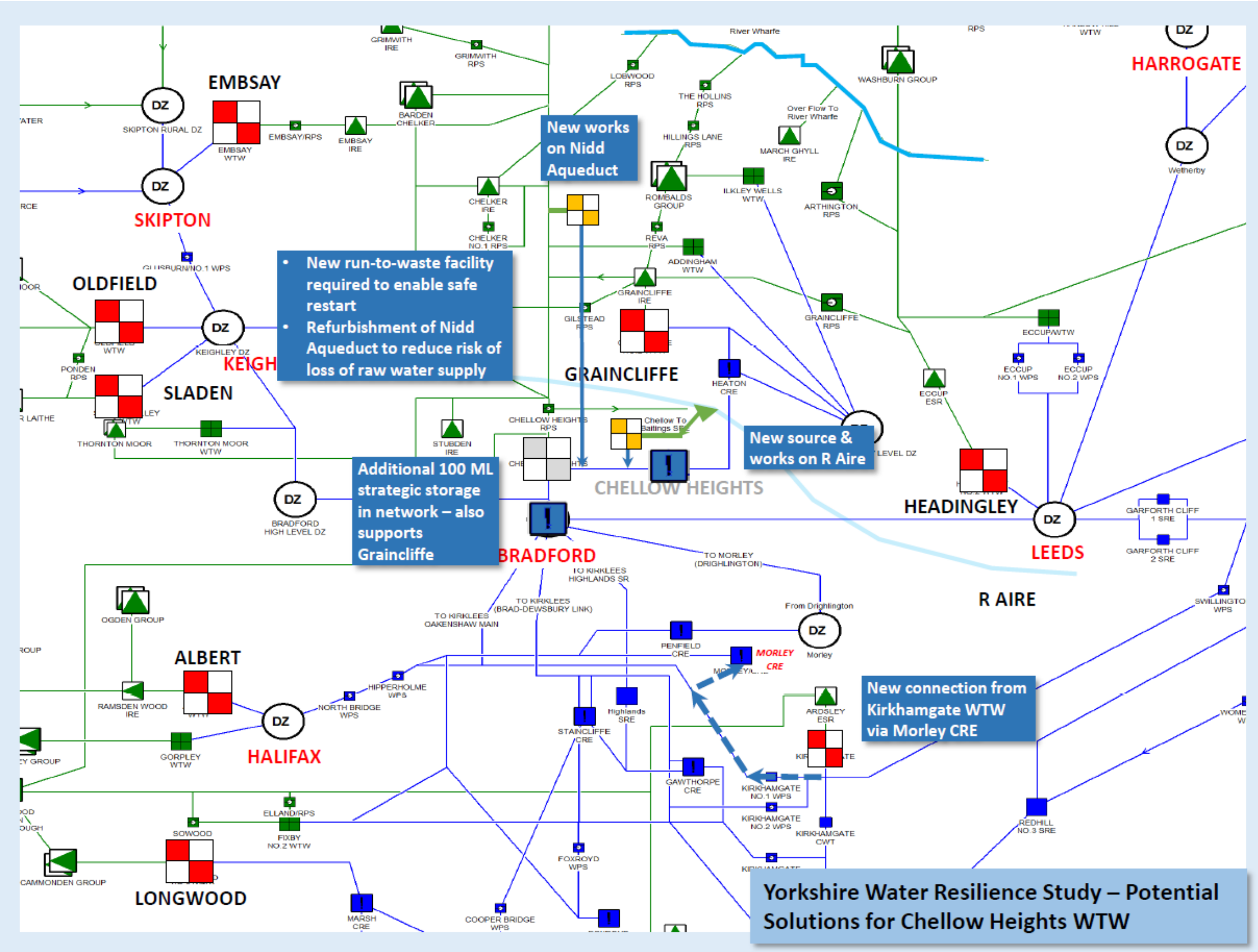


Figure. 11: Example resilience study output.

2.2.4 High level summary of long-term strategy

This section provides an overview of our future strategy in relation to several key water quality risks. It is underpinned by the principles of catchment management and resilience but gives more detail about how we intend to respond to particular risks.

2.2.4.1 Raw water deterioration – colour

We are working with the EA and other key catchment stakeholders to further develop our approach to restoring the condition of the peat uplands of Yorkshire. This will take the learning from research by Leeds University along with the experience of what our current interventions have delivered, and develop an improved approach for the future.

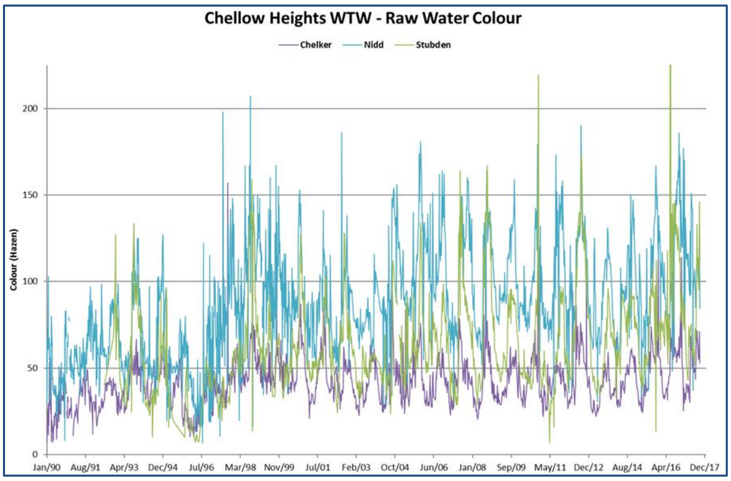


Figure. 12: An example of raw water deterioration.

We are also developing several schemes with catchment stakeholders to investigate how collaboration will deliver additional natural and social capital benefits for customers, biodiversity and water quality.

2.2.4.2 Raw water deterioration – pesticides

We have reviewed the risks posed to our water sources by pesticides, clarifying where we need to understand the risks better and where we need to act. We are clear that Yorkshire needs a vibrant agricultural economy, hence our approach to acting collaboratively with farming communities and their advisors where possible. Metaldehyde remains a particular challenge to compliance as a result of its use within the large lowland river catchments of Yorkshire.

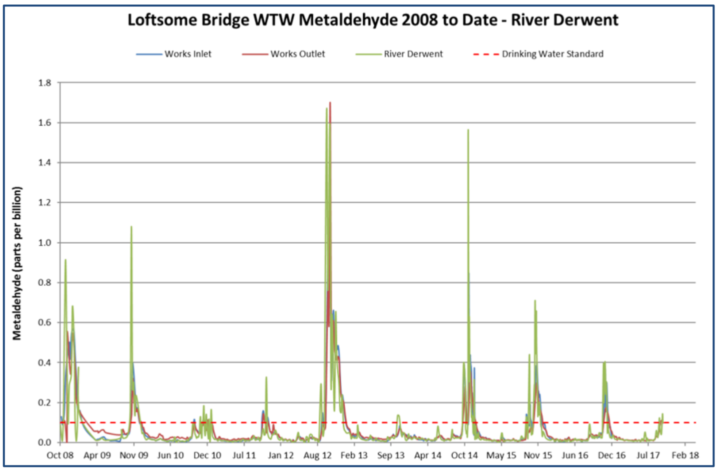


Figure. 13: An example of metaldehyde trend at abstraction.

Although we have seen progress made, there remains a significant risk, and the challenge will be to transfer our learning from the past 8 years of investigations and pilot catchment trials, to larger areas of our catchments. This is key to ensuring the many other benefits of a catchment based approach are accrued in terms of reduced risk to raw water quality. As part of this approach we have identified further actions which can be taken by us, Catchment Sensitive Farming and the arable sector to eliminate this risk to water quality by 2025.

2.2.4.3 Ground water – nitrate, pesticides and saline intrusion

During AMP6 we have been investigating the potential sources of nitrate in a number of our groundwater sources where trends predict future risk of non-compliance. Within the WINEP, we are developing a programme of interventions for AMP7 to limit these trends and over time improve the quality of water abstracted.

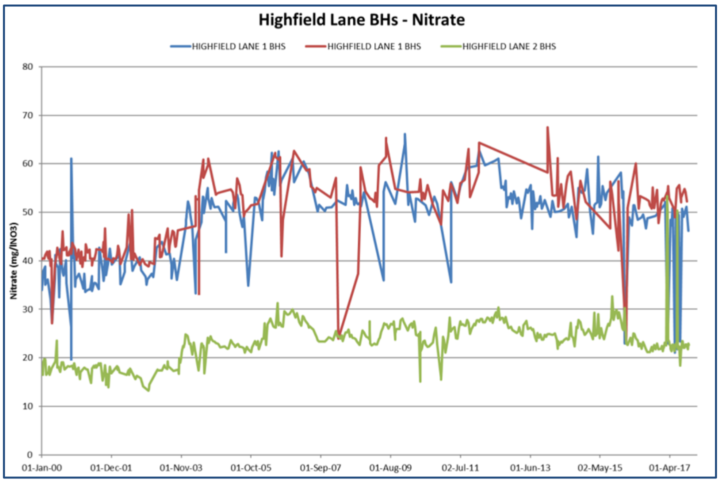


Figure. 14: Example of increasing nitrate trend.

We have identified a small number of groundwater sources where unusual detections and trends in pesticides have been seen. Within WINEP we are proposing a series of investigations to better understand the sources and pathways of these materials, so that we can plan interventions in the future to prevent further deterioration.

Compared with conventional engineering solutions, nitrate catchment management comes with its own challenges and uncertainties, such as the time-lag of impact expected at groundwater level, which is influenced by:

- The geology and hydrogeology of the source catchment zones;
- The uncertainties of the level of reduction that can be expected at abstraction sources; and

- The challenge to securing long-lasting behavioural change at catchment level.

Nevertheless, if business as usual is to be maintained, groundwater nitrate concentrations in the Yorkshire region will continue to rise, increasing the need for new nitrate removal plants at significant cost. Catchment management has the potential to reduce nitrate leaching to groundwater, delay or avoid the need for additional treatment plants, and in the long-term, produce possible trend reversal in groundwater nitrate concentrations. None of which could be achieved by conventional engineering solutions. Finally, a small number of groundwater abstractions are at risk of saline intrusion into the aquifer which could impact on water quality and availability. We are planning investigations to ensure we understand the mechanisms by which this may occur and the implications for future water resources.

2.2.4.4 Other raw water deterioration – algae & *Cryptosporidium*

There are a small number of sources which are facing deterioration as a result of other factors. A few sources are seeing increased algal activity as a result of factors such as increased nutrients and climate effects. This has a number of impacts on our production of drinking water by increasing the solids loading on treatment and producing natural products which impart tastes and odours to water.

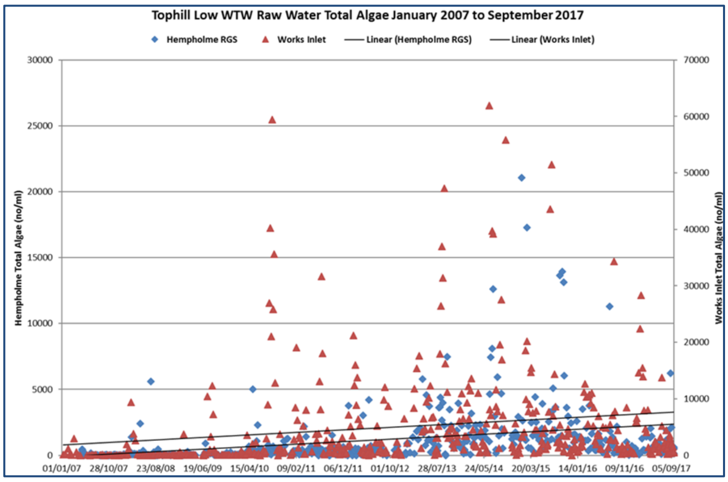


Figure. 15: Example of total algae increasing trend.

In other sources, we see increasing levels of *Cryptosporidium* in the water we abstract, in some cases due to the impact of wildlife such as geese and gulls using water bodies as roosting places. In both cases we keep under review the potential mitigation available to prevent this deterioration in raw water quality. Later in this document we identify one case where this has not been practicable due to other constraints.

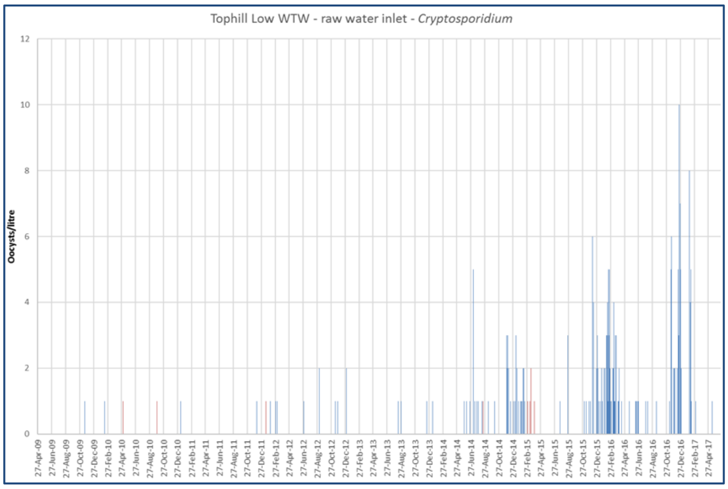


Figure. 16: *Cryptosporidium* detections at Tophill Low WTW.

2.2.4.4 Water Treatment Works performance

As part of the supporting work for this submission and the draft WRMP, we have undertaken a review of what our treatment works can deliver and what we require for the future, in terms of both quality and quantity. We have identified key actions which will allow us to deliver more reliable and resilient water production. This is focused on the key areas of maintenance and the prevention of and recovery from equipment failure to improve reliability, including:

- Good practice in maintaining assets, in particular for dosing systems and monitoring and control systems.

- Pro-active preventative replacement strategies and / or fail-safe back up facilities to reduce risk.
- Improved reliability and use of on-line monitoring systems to improve responsiveness.
- Developing a plan to retro-fit run to waste systems on all WTW.

2.2.4.5 Distribution network – acceptability (discolouration)

Within AMP6 to date, we have delivered a significant reduction in the numbers of times customers contact us about discolouration of their water supply. We plan to achieve a further reduction in the risk of unacceptability of water to our customers, recognising that the aesthetic reduction in quality undermines our customer's confidence in our water supply. We have introduced new techniques in AMP6 and will demonstrate within this document how this will achieve the shared goal of the Company and Inspectorate over time (see section 4.6.2). In addition, our approach is satisfying our requirement for better information regarding the condition of our network and approaches for targeting future interventions.

We have achieved this by the widespread use of uniform flushing to mobilise and remove sediment from our water distribution mains. Simultaneously we also gather data which helps us understand the amounts of material present and the future need for maintenance. We have deployed a similar approach to reducing the risk from deposits within trunk mains, based on research from Sheffield University, which allows us to manage water quality risk in a non-invasive way. We propose continuing these approaches into AMP7, but are also planning a programme of innovation, which will further develop and make better use of these techniques and provide new approaches.

2.2.4.6 Distribution network – acceptability (taste and odour)

One of the key areas of water acceptability and one that we receive contacts from customers is taste and odour. This has three primary sources:

- Raw water (for example, algal content)
- Chlorine acting with compounds in the treated water (for example, bromides)
- Interaction between plumbing and materials within the customer's property (usually plastic fittings, such as the tap)

We have an active programme of chlorine optimisation, focused on our secondary dosing units and managed by a dedicated team of technicians. The aim being to maintain stable low levels of chlorine throughout the network. In some cases, the complaints are not directly related to chlorine itself but to its interaction with plastic fittings within the home. In some areas where water chemistry makes such occurrences more likely, we condition the water using chloramination to avoid this issue. We are considering where we can extend the coverage of this approach during AMP7, without constraining the flexibility of the supply system.

2.2.4.7 Distribution network – lead

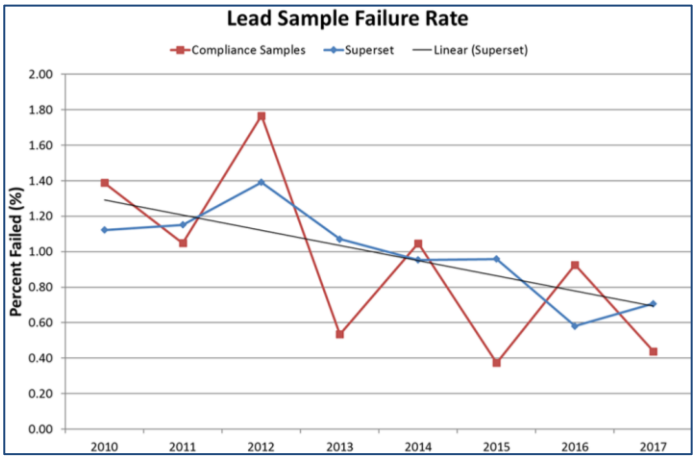


Figure. 17: Lead sample failure rate

We recognise the need to plan for the long-term in seeking solutions to the issue of lead. We make proposals in this document which make further moves in this direction, but focus in the short-term on managing risks for vulnerable groups and understanding better potential barriers to future activity. In the context of development of a long-term plan for lead, it became clear that the focus needs to balance the needs for progress in reducing the risk over the coming AMP, with defining the actions which will facilitate the long-term goal. So, research and development will feature in our plans, alongside activity to identify the changes needed to local and national policy in the areas of housing and public health.

2.3 What we want to achieve in AMP7

Our objective is to deliver upper quartile water quality performance by the end of year three of AMP7 (2022/23), targeting a Compliance Risk Index of 0.9-1.6. In order to drive this performance, alongside this submission, we have set ourselves an improvement plan with some challenging internal targets. This improvement plan seeks to drive performance through application of the totex hierarchy, prioritising risk mitigation at source, followed by ensuring the operability and resilience of existing assets, before we consider treatment options.

To achieve these challenging internal targets, will require us to review our processes, including maintenance; control room alarm handling; incident response; promotion; planning and scheduling of work, as well as water resource allocation planning and water quality procedures and processes. In order to build our resilience further, we will take a predictive and proactive approach to Water Treatment Works maintenance; improving asset stability, reducing down-time and increasing asset availability. This will be supported by a new operating model trial at five of our critical sites, where there will be additional focus on availability and process safety.

Our goal is to improve drinking water quality, but this is against a background of raw water deterioration, especially with respect to colour (DBP risk). Whilst we would prefer to achieve this improvement through upstream interventions, there are some cases where the forecast time to failure means this is not possible. In these cases, we have included treatment options in this submission to mitigate the risk in AMP7. In cases where we consider treatment options to be required, we will pursue a twin-track approach to ensure compliance in the short-term through incremental improvements in treatment capability, co-ordinated with catchment activity to reduce the risk over the longer term.

These treatment schemes and our approach to reduce and eliminate exposure to lead are the areas that we specifically seek technical support from the Drinking Water Inspectorate for the inclusion of these proposals in our

PR19 submission to Ofwat. Further information is provided on these specific schemes in Part B of this document, with detailed information contained in the Annex.

3.0 Catchment management and the water industry national environment programme

Overview

In AMP7 we are planning to invest significantly more in upland catchment management and resilience than we have in previous AMPs. Our forecasts indicate that there are around 60 water sources where catchment only interventions are the most appropriate to manage the risk of raw water quality deterioration in the medium and long-term. Over AMP6 we have evaluated the potential effectiveness and technical approach to catchment management for metaldehyde and nitrate. In AMP7 we are substantially upscaling catchment management for metaldehyde and deploying catchment management of nitrates for the first time. Therefore, our catchment management programme covers a range of risks to water quality including:

- Colour arising from peat degradation
- Pesticides
- Nitrate
- Saline intrusion

We plan to invest circa £9 million in catchment activity to address colour from upland peatland deterioration in the period 2020-2025, along with circa £7 million on reducing the risk of metaldehyde entering our rivers. This catchment activity forms part of the Water Industry National Environment Programme which we agree with the Environment Agency. We reference this activity in this submission to ensure visibility of the mitigation of medium and longer-term drinking water safety planning risks.

Metaldehyde remains a significant risk to compliance in those supplies drawing from the large lowland rivers of North and East Yorkshire. We do not propose any treatment solutions at our water treatment sites in the period 2020-2025, as we do not believe that treatment solutions are the most cost-effective solution. We will continue to work collaboratively with land owners and other stakeholders to manage the risk at source. An example of our proposed approach is to include the provision of resource through Natural England to provide Catchment Sensitive Farming Officers. We are funding these Officers within Natural England, to work with the agricultural sector to reduce pesticide and fertiliser use, and to enhance soil health.

These Officers will:

- Influence farming practice
- Work with the supply chain for arable products to promote metaldehyde free approaches

- Develop a system for the "loan" of equipment which allows access to new farming technology for small farms.

We will broaden and deepen our commitment to catchment management over the next five years and beyond. Our upland catchment management has currently focused on restoring past damage and preventing further damage taking place. We recognise the need to improve the upland catchments of Yorkshire, those we own, and those owned by others, as this is the most appropriate means of preventing further deterioration in raw water quality. Our AMP7 plan recognises this requirement and is more ambitious than previous plans, as we seek to restore active peat formation to achieve functioning ecosystems. Through a collaborative approach we will continue to protect and improve Yorkshire's water environment.

We have taken our learning from collaboration in the uplands, and are now applying this to improving lowland catchments. Collaboration helps deliver:

- Better value - speeding up research
- Practical delivery of research findings
- Cultural change
- Engagement.

For this reason, it is a major element of our approach to catchment management and will be measured using our performance commitment "working with others".

Our AMP6 catchment programme was incorporated into the EA's National Environment Programme. Our catchment management programme for AMP7 has been included by the EA within WINEP-2. We are working to develop the scope and costings needed to confirm the programme within WINEP-3. A key area of debate is around the need for multiple interventions on peatlands to secure conditions which protect water quality for the long-term. The activity undertaken in this and the previous AMPs can be viewed as repairing the hydrology of the catchment. For catchment management to be a long-term solution, there is a need for a further phase of restoring a functioning bog community, dominated by *Sphagnum* moss.

In summary, our catchment management programme covers a range of specific water quality parameters including colour, pesticides, nitrate and saline intrusion on reservoir, river and borehole sources. It covers both implementation and investigations. The upland management schemes for colour will deliver a wide range of additional benefits to our customers and stakeholders, including flood risk attenuation, carbon mitigation and biodiversity. The programme will also contribute to resilience to climate change, which is a current risk identified under our climate change Adaptation Reporting requirement.

We consider that our catchment programme is consistent with specific guidance, and has support for the approach, from Defra, the EA, Natural England and the DWI.

4.0 Specific Water Quality Risks

4.1 Overview

There are three main types of raw water within the Yorkshire region, as shown in Figure 18. The rivers in the North and East of Yorkshire supply circa 33% of the regions drinking water. Reservoirs towards the South and West of Yorkshire supply the largest proportion, 45%, with groundwater sources in the East and South of Yorkshire supplying circa 22%. Each source has its own associated water quality risks as discussed in section 2.2.2 Future Challenges, Table 5.

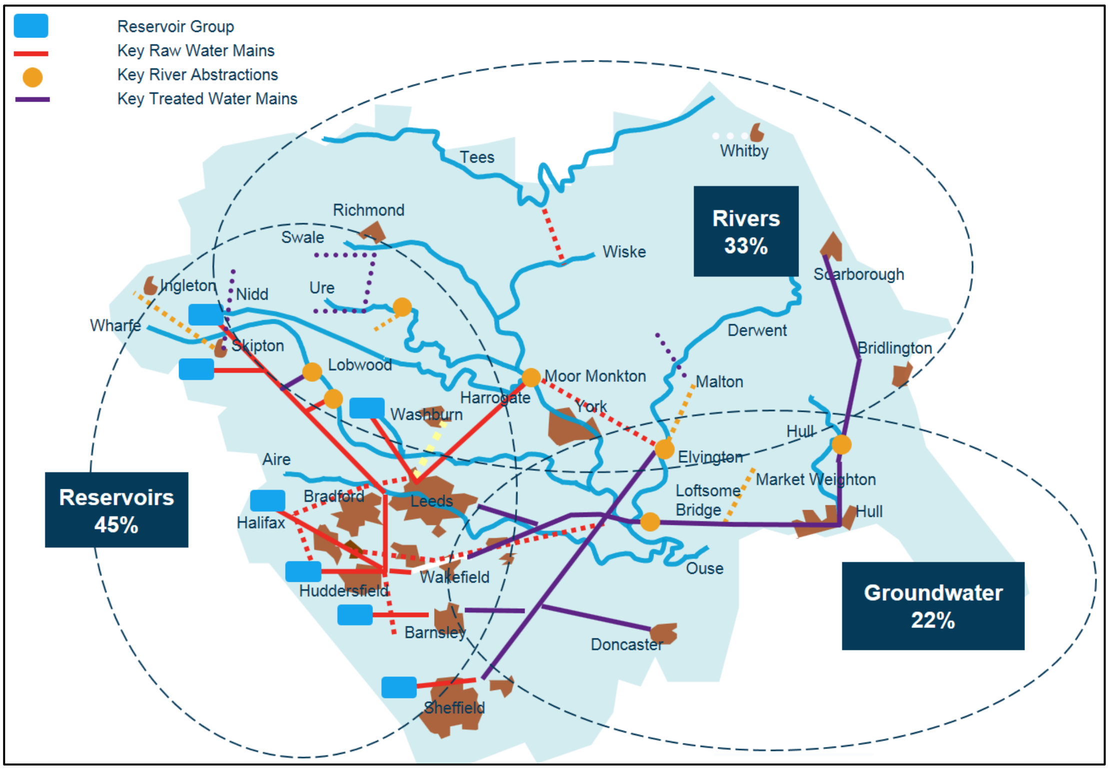


Figure. 18: Main sources and locations of raw water in the Yorkshire region.

This section describes the specific risks and hazards that we have identified through our DWSPs and require long-term improvements. These proposals have been based on customer feedback, the analysis of raw water data, operational feedback, outcomes from operational events and reviewing treated water.

We have considered proposals to carry out improvements for drinking water quality and the aesthetic quality of water across a broad set of considerations, when we are planning for the long-term. These considerations are consistent with those listed within the DWI Guidance Note: “Long-term planning for the quality of drinking water supplies” They encompass:

- Risk assessment
- Catchment management

- Resource and supply management
- Raw water deterioration
- Pesticides
- Water treatment
- Water distribution
- Lead
- Other point of use considerations
- Radioactivity
- Other enduring or emerging risks

Proactive management

Our proposed programme of work continues with our approach of catchment management as a primary strategic intervention to address deteriorating raw water quality. Where catchment interventions are unlikely to deliver benefits in the timeframe required to mitigate the identified risk, we will invest in further treatment.
Where a risk has been identified, we mitigate the risk through operational action to minimise the risk of failure. The impact of this mitigation has been considered throughout the risk assessment. Short, medium and long-term interventions have been considered to understand how the risk to customers can be minimised.

Twin track integration of catchment management and treatment solutions

Where we have identified an unacceptable risk to customers that cannot be mitigated in the time to impact by catchment management, we are proposing a treatment option. For six of our WTW, the inherent uncertainty of time to resolution for catchment management options means that we consider the only feasible solution to manage the risks appropriately, to be the enhancement of treatment capability at the site.

Treatment solutions

We have identified several unacceptable risks which require a treatment solution in AMP7. Many treatment solutions are as a result of the need to mitigate increasing colour trends from our upland water sources. Section 4.2.1 discusses of the risks we face in our region from disinfection by-products as a result of deterioration in upland coloured waters. This includes a summary from a study completed by Leeds University that identifies why our region is at a greater risk from deterioration in upland coloured waters than any other area of the United Kingdom.

Following an assessment of the magnitude of future risk we have identified three solution routes:

1. The construction of additional, similar treatment process units alongside the existing equipment. This is effectively de-rating the process loading rate and bringing the process back to design capacity. An example of this would be the construction of additional rapid gravity filters to resolve increased particulate loads due to increased colour and coagulant entering the clarification stage.

2. The construction of additional "conventional" process stages, following the existing treatment process train. An example of this would be the construction of a second stage of filters to better separate solids from water prior to chlorination.
3. The construction of an additional innovative process proceeding or within the existing treatment process. An example would be the introduction of an ion-exchange process as pre-treatment before the coagulation/clarification stage on an existing treatment works.

Impact of high dissolved organic carbon.

A high dissolved organic carbon (DOC) in water causes a number of problems at WTW:

- It increases the solids load passing forward onto the existing process units, many of which were designed with raw water parameters significantly lower than currently experienced.
- The nature of the DOC results in a weak flocculent structure, which is susceptible to shear forces present within subsequent clarification and filtration processes, this results in high clarified and filtered turbidity. At times of high colour, the only solution is to restrict the throughput through the treatment works to maintain quality. This results in a challenge to our supply and demand balance.
- In addition to the throughput issues, when this high DOC occurs in the summer and autumn, the residual DOC after treatment, can reach a level which leads to elevated disinfection by-product formation.

The ion-exchange process addresses all of the above problems in the following way:

- It is located at the inlet to the WTW, where it reduces the concentration of DOC, up-stream of the existing treatment processes, effectively bringing the raw water DOC closer to the original design parameters, thus improving the treatment works resilience.
- It selectively removes fractions of DOC in the mid to low molecular weight (<5 kDa) and is very effective at removing the lower molecular weight (<3 kDa) organics known to be difficult to remove by coagulation. Coagulation is highly effective at removing the higher molecular weight >5kDa material. Thus, a combination of both magnetic ion exchange (MIEX) plus coagulation gives an overall enhanced removal of DOC.
- Enhanced DOC removal reduces the solids load going onto the existing processes, enabling full throughput to be maintained under all raw water conditions. The removal of a specific fraction of DOC results in a stronger flocculent, more resistant to shear.
- It provides enhanced removal of THM precursors, thought to be associated with the lower molecular weight fraction that coagulation does not target.
- It does not require the abandonment of existing processes.

It is the combination of these benefits which gives the ion-exchange process an advantage over other solutions.

Some parameters of MIEX treatment are capable of significant modulation which allows the degree of treatment to be matched to the raw water risk (DOC/colour). In particular, the ratio of flow through to bypass flow can be varied, and the regeneration rate of the resin adjusted. This allows for flexible enhancement to the treatment process and reduces the cost and environmental impact when not required. This is very different to say, the option of using Granular Activated Carbon (GAC) as a DOC scavenger before chemical disinfection. As a result of the long lead times to regenerate GAC, the capability has to be available at all times in order that it is effective when the raw water deteriorates.

Further development of this approach

Since the enhancement of three WTWs by MIEX during AMP4 there have been two enhancements to the innovative ion-exchange process which make it more cost-effective:

1. A new resin has been developed, with slightly larger pores, designed to specifically address the issue of high molecular weight DOC inhibiting access to the porous structure.
2. A high rate contactor has been developed which combines the mixing and separation elements in a single vessel, the benefit of this is a significantly smaller footprint, less civil work for large systems (concrete designs), and opportunity to use pre-assembled skid mounted systems.

We are currently constructing a WTW that incorporates the advantages of these enhancements. This site will be operational prior to the design activity starting for AMP7 solutions, this provides us with confidence in the potential solution.

We are planning research and development activity in the interim to identify whether other similar technical solutions are available. We will be able to investigate their feasibility in sufficient time to give design choices for our AMP7 schemes.

The treatment solutions are presented in detail in Part B and the annex of this submission. All solutions are developed on a whole life cost basis, based on the technology available today. To put forward a solution based on any other basis than current technology would leave customers exposed to water quality risks and/or our ability to deliver the solution for our final price determination from Ofwat.

4.2 Specific Water Quality Parameters

4.2.1 Disinfection by products risk driven by deterioration in upland coloured waters

YW operates circa 130 Impounding Reservoirs which are generally on the eastern slopes of the Pennine chain. As part of the development of our approach for PR19 we have assessed all strategic sources at asset level, and less significant sources at the reservoir group level, to understand the trends in raw water quality and their consequences for future water quality.

During 2013 the DWI issued specific, detailed guidance on its approach to the minimisation of disinfection by-products. The background to this guidance was the linkage to Regulation 26 compliance which states: "*The Water Supply Regulations 2010 (SI 2010 No.991), which apply in England and Wales introduced an amendment to Regulation 26: This disinfection by-product rule of the 1998 EU Drinking Water Directive requires water companies to "design, operate and maintain the disinfection process so as to keep disinfection by-products* *as low as possible without compromising the effectiveness of the disinfection; and to verify the effectiveness of the disinfection process"*

In addition, companies should ensure:

"that before supplying water, a water company must disinfect the water and subject it to sufficient preliminary treatment to prepare it for disinfection"

In line with the DWI Guidance, published in 2010, the evaluation we have undertaken, used a screening criterion consistent with our approach in PR14 of an annual average value of <50µg/l (50% of the THM standard) for each WSZ. This was used as a broad indicator that, generally, disinfectant by-products(DBPs) are being minimised effectively. Whilst the <50µg/l average value is useful as a high-level screening tool, it does not take account of the degree of challenge faced by the WTW supplying the WSZs, principally as a result of the quality of raw water. For some supplies, especially those sources derived from highly coloured, upland raw waters, the minimum achievable average THMs could be significantly higher than <50µg/l total THMs, within the constraint of currently deployed technology. In developing our proposals for PR19 we have followed similar processes to previous reviews in looking at sources where deterioration in raw water is continuing, where this causes the levels of DOC to approach the limits of treatability for the installed processes, and to assess when such thresholds may be crossed and a DBP risk could materialise.

Through this evaluation process, we have identified 5 WTW where we consider the need for additional control measures, in the form of enhanced treatment is required.

4.1.1. Summary of Leeds University review of Yorkshire peatlands

This section explains the work that has been undertaken by Leeds University to understand why the degree of degradation and water quality deterioration is more pronounced in the uplands of our region, than elsewhere in the United Kingdom. This research is important in supporting our twin track catchment management and treatment process approach in AMP7 and supports our understanding of why catchment management alone cannot mitigate the DBP risk in the short term.

UK peatlands are dominated by extensive areas of blanket bog, which is at the warmer and wetter end of the climate parameters associated with northern peatlands. This implies that variables such as precipitation, frequency of storm events and drought, are more likely to have a significant year-on-year and seasonal effects on carbon flux rates in UK peatlands, compared to those developed under more continental climates.

Why is water colour so high in Yorkshire region?

- Coloured water, with high concentrations of DOC, is observed in catchments with a high proportion of organic soils, such as peat, this controls the size of the carbon pool that is available for export (Chapman et al., 2017, part 1).

A large proportion of peat blanket bog found in England and Wales is within the YW region (see Table 7 from report by Chapman *et al*., 2017, part 1 below). The three regions in the table below, that lie within the YW region (bold and italics) account for 34% of all blanket peatland in England and Wales. In addition, circa 45% of all drinking water in YW is sourced from these peatland areas.

Table 7: Distribution of blanket peat in upland areas of England and Wales in comparison to whole of Scotland (from report by Chapman et al., 2017 and adapted from Clark et al., 2010).

Upland region	Area of blanket peat (km^2)	% of total in Great Britain
North York Moors	***40***	***0.3***
Brecon Beacons & S. Wales	52	0.3
Dartmoor, Exmoor & Bodmin moor	146	0.9
Cumbria Fells & Dales	182	1.2
Cambrian Mountains, Wales	209	1.3
Northumbria	325	2.1
Peak District	***476***	***3.0***
Snowdonia & N. Wales	718	4.5
Yorkshire Dales & Bowland	***765***	***4.8***
Total	3604	22.8
Scotland	12226	77.2

The blanket peat in Yorkshire is highly degraded. Soil degradation occurs when human induced phenomena lower the current and/or future capacity of the soil to support vegetation and animal life (see Table 7 from Holden et al., 2007). Soils are generally resilient to change within certain limits, but outside these limits the soil will not recover naturally, even if the pressure is removed. Most organic soils support ecosystems that are sensitive to pollutant impacts and human activities. These soils are very susceptible to degradation. Peatland degradation is often characterised by:

- A reduction in species diversity.
- A reduction in the cover of Sphagnum species compared to the historic past.
- An increase in the area of discontinuous plant cover (bare peat).
- A reduction in the rate of peat accumulation due to decline in water table and Sphagnum species.

In addition to direct human activities, climate change may trigger these characteristics by disturbing the delicate hydrological balance of organic soils.

1. The climate in Yorkshire, is warmer than more northern blanket peats e.g. Scotland, meaning that decomposition rates are higher and thus more DOC/colour is produced. High rainfall in the west of our region means that the peat and river network is well connected and DOC that is produced in the peat is delivered to surface waters. Our warm and wet climate is ideal for colour production and delivery to surface waters.
2. The geology of the Pennines means that blanket peat covers the top of the catchments. In Wales and Scotland catchments contain larger areas of steeper land where soils on the high ground are thin. This results in catchments which do not contain such high proportion of exposed deep blanket peat, and do not contain as much carbon. In our region, the natural drainage networks appear denser and the stream channels deeper (steep banks), which perhaps may suggest shorter/better connectivity between the organic soils and streams than other upland areas.

The peat soils in Yorkshire are particularly vulnerable to degradation due to a combination of the following reasons:

- Surrounded by highly populated areas e.g. Manchester, Sheffield, Leeds, they have been extensively used for farming, recreation and game birds, with subsequent disturbance effects such as erosion, artificial drainage, heather burning, modified vegetation cover.
- They have been impacted by current and past pollution, especially acid rain and heavy metal deposition.
- Peat in our region is climatically vulnerable as it sits at the lower edge of the bioclimatic spectrum, based on models that include measures of both hydrological conditions and maximum temperature under scenarios of climate change (Clark et al., 2010).

The blanket peat in our region has been heavily grazed by sheep, intensively drained and heather has been burnt for grouse management. In the Yorkshire Dales National Park approximately 60% of peat moorland has been subjected to machine ditching (Backshall *et al*., 2001).

Degradation of the peat results in:

- Increased erosion and loss of particulate peat into the watercourses and reservoirs, where it is deposited, resulting in lower water holding capacity of the reservoir.
- Increased decomposition of the peat as the water table is lower and decomposition is faster in aerobic conditions than anaerobic (see Chapman et al., 2017, part 1). This results in the loss of carbon to the atmosphere as carbon dioxide (CO2) and particulate organic carbon (POC) and DOC to the aquatic ecosystem. The results of this being that the water becomes more coloured.

Why is peatland restoration a good thing?

Restoration of peatlands, via a number of mechanisms as outlined below, can result in the following:

- Increased vegetation cover (reseeding of bare peat)
  - Diverse vegetation cover including a large proportion of *Sphagnum* slows the flow of water across the catchment. This reduces runoff and downstream flooding (see Holden et al, 2012 and Gao et al., 2017). It also reduces flux of high DOC/coloured water by optimising microbial degradation of DOC prior to arriving at a WTW (Holden et al., 2013).
  - Diverse vegetation cover stabilises soil temperature and controls microbial production of DOC potentially resulting from increase in air temperature.
  - Complete vegetation cover reduces erosion of POC which can be deposited in reservoirs and transformed to DOC/colour in the river network.
- Blocking of drainage ditches.
  - Raises water table which slows the flow of water from catchment and results in decline in decomposition of peat to DOC and CO_2 (Chapman et al., 2017 part 1).
  - Reduces peat erosion and loss of POC.
- Maintaining a more stable water table that is nearer to the peat surface.
  - The higher water table buffers the effects of the drying-wetting cycles that produce colour/DOC.
  - A Drought will result in the lowering of the water table. If the water table is low (degraded) this will result in an increase in drought events and also increase in water colour.

Restoration of the peatland can:

- Mitigate against climate change, the carbon is stored as peat, resulting in less CO2 emitted to atmosphere.
- Reduce water colour production via decomposition.
- Reduce peat erosion into reservoirs and watercourses.
- Reduce the speed at which the water flows. The water flows more slowly across the catchment and helps reduce downstream flooding.

Vegetation cover can affect the velocity of the water flowing across blanket bog. Holden *et al*. (2008) showed, using plot-scale measurements, that *Sphagnum* was very good at slowing the velocity of the water across peat surfaces compared to sedge-covered surfaces and bare peat surfaces. The values for flows across *Sphagnum* were typically almost an order of magnitude slower than for bare peat (Holden *et al*, 2012). Larger flood peak attenuation is predicted to occur when *Sphagnum* is distributed in stream buffer zones than when it occurs across hilltops (Gao *et al*., 2017). The magnitude of surface cover type effects on flow peaks also depends on the size of the storm event and the topographic characteristics of the catchment in question (Holden *et al*, 2012).

Table 8: Past and present pressures on organic soils and the wider environment (from Holden et al., 2007).

Pressure	Impact on soil quality	Impact on wider environment	Remedies
Climate change Increased temperatures and incidence of summer drought Increased winter rainfall and storms	Changes in rates of organic matter decomposition and nutrient cycling, loss of organic carbon, episodic acidification of peat waters during droughts Reduced impacts of frost	Vegetation change, increases in carbon flux from terrestrial stores into more reactive (riverine, marine and atmospheric) pools, destabilisation of peatlands, increase in emissions of CO_2 to atmosphere and thus contributing to further climate change, effects on water transparency, acidity and metal toxicity, effects on drinking water quality Longer growing seasons Greater frequency of wildfires	Emission reductions through coordinated abatement strategies
Land use and management Afforestation/Deforestation	Changes in organic matter type and accumulation with subsequent impact on nutrient cycling, acidification	Acidification of surface waters, loss of moorland habitat	Guidelines for planting on organic soils
Peat extraction	Soil erosion	Loss of habitat, carbon release	Restricted licences
Drainage	Soil erosion	Carbon release, water discolouration, increased flood risk, stream ecology loss and reservoir infilling	Block drains (note that peat functions are not always reversible)
Burning of heather	Soil erosion, soil structural change	Carbon release, water discolouration	Guidelines
Grazing	Soil erosion, compaction, loss of structure	Increased flood risk, vegetation/permanent change if over-capacity	Reduction in stocking rates, fencing to limit livestock access, mixed herds/flocks
Fertiliser use	Changes in nutrient cycling	Eutrophication of surface waters	Guidelines (e.g. Nitrate Vulnerable Zones)
Liming	Increase soil pH, which has an impact on soil biota and vegetation, increased decomposition of organic matter	Increase leaching of nutrients and base cations	Guidelines
Mining	Burial and turnover of topsoil Erosion	Loss of organic soil store Water pollution (high or low pH, metals, sediment)	Treatment wetlands
Pollutant deposition Heavy metals	Negative impacts on soil microbial biomass, processes and diversity	Pollution of water courses, uptake into vegetation and human food chain	Reduction in the emissions of heavy metals
Deposition of sulphur and nitrogen	Soil acidification leading to changes in decomposition rates and nutrient cycling, nitrogen saturation	Vegetation change, acidification and eutrophication of surface waters	Emissions reduction through coordinated abatement strategies

A full list of references for this study is available in Appendix 1.

4.2 Nitrate

Nitrate is not currently seen as a significant future risk for Yorkshire Water, the blending and treatment solutions which were implemented over the past AMPs remain as robust solutions. However, we need to ensure that raw water nitrate levels are stabilised and where achievable reduced to assure the sustainability of existing treatment or blending solutions.

During AMP6 we have undertaken substantial groundwater investigations, under the NEP, to identify the key sources of nitrate and possible routes to their mitigation. These studies looked to understand the complete nitrate cycle and identify effective catchment management approaches. These approaches have informed a long-term sustainable groundwater nitrate management strategy for our abstractions.

We favour the catchment management approach to reducing inputs into the catchments, and these have been identified as primarily being agricultural in origin. This approach is consistent and synergistic with the range of activities already being undertaken to manage the risks of metaldehyde.

Additional benefits accrue from the opportunity to work with land users and raise awareness of other problems. For example, the setup of communication channels can assist with reducing nitrate contamination of surface water; pesticide contamination of surface and groundwater and sediment loss. We are working with the EA to ensure that the outcomes of the above research are embedded within the WINEP

4.3 Customer acceptability - Taste & Odour

4.3.1 Algal derived

The drinking water safety planning process, has identified one of our sites where a more resilient treatment solution is required to mitigate hazards derived from algae. These hazards are increasing in severity, and over time will result in more frequent materialisation of risks to drinking water quality or customer acceptability. The hazard is associated with increased loading of algae from the river and raw water storage reservoirs, which leads to concentrations of methyl isoborneol (MIB) and geosmin which trigger customer contacts, both at background levels (chronic) and as a water quality event (acute).

Short-term mitigations such as the use of barley straw and dosing of powdered activated carbon (PAC) have had limited effect, and the latter has significant impact on the key treatment processes which are relied upon for the production of compliant water.

Longer term we have identified the appropriate totex option is to intensify the treatment process capability for the removal of MIB and geosmin. We are submitting a scheme for enhanced treatment as detailed in Part B of this submission.

4.3.2 Chlorine derived

We receive several hundred contacts from customers regarding tastes and odours which are not of chlorine directly, but are rather a function of the interaction of residual chlorine with phenol donors within the customer's premises. During AMP5 we installed treatment to provide additional areas of the region with chloraminated supplies. This was very successful in minimising this type of contact in the area treated. During AMP6 we have added additional areas to reduce the overall number of contacts further. There remains a risk of customer contacts in specific areas of Yorkshire and we are considering base maintenance investment at a small number of sites to mitigate this.

4.4 *Cryptosporidium*

Cryptosporidium is a parasite that causes severe gastroenteritis and can survive chemical disinfection. We undertake continuous monitoring at those WTW where we observe a significant risk of the presence of this organism in treated water, as a result of its occurrence in raw water.

For surface water sites, particularly where directly river derived, we require 4 log removal across the treatment process, which may include raw water storage where appropriate.

As part of our DWSP reviews, we identified one of our sites with an increasing raw water risk. We have proposed a solution to this risk at our Tophill Low WTW, this is detailed in Part B.

4.5 Metaldehyde

Metaldehyde remains a significant risk to compliance in the supplies abstracting water from the large lowland rivers of North and East Yorkshire. This is an area of circa 5,000km^2, much of which is in used for arable farming.

The presence of metaldehyde is normally at the greatest during the Autumn period when winter cereals and oil seed rape crops are being established, particularly following heavy rainfall events within the catchments.

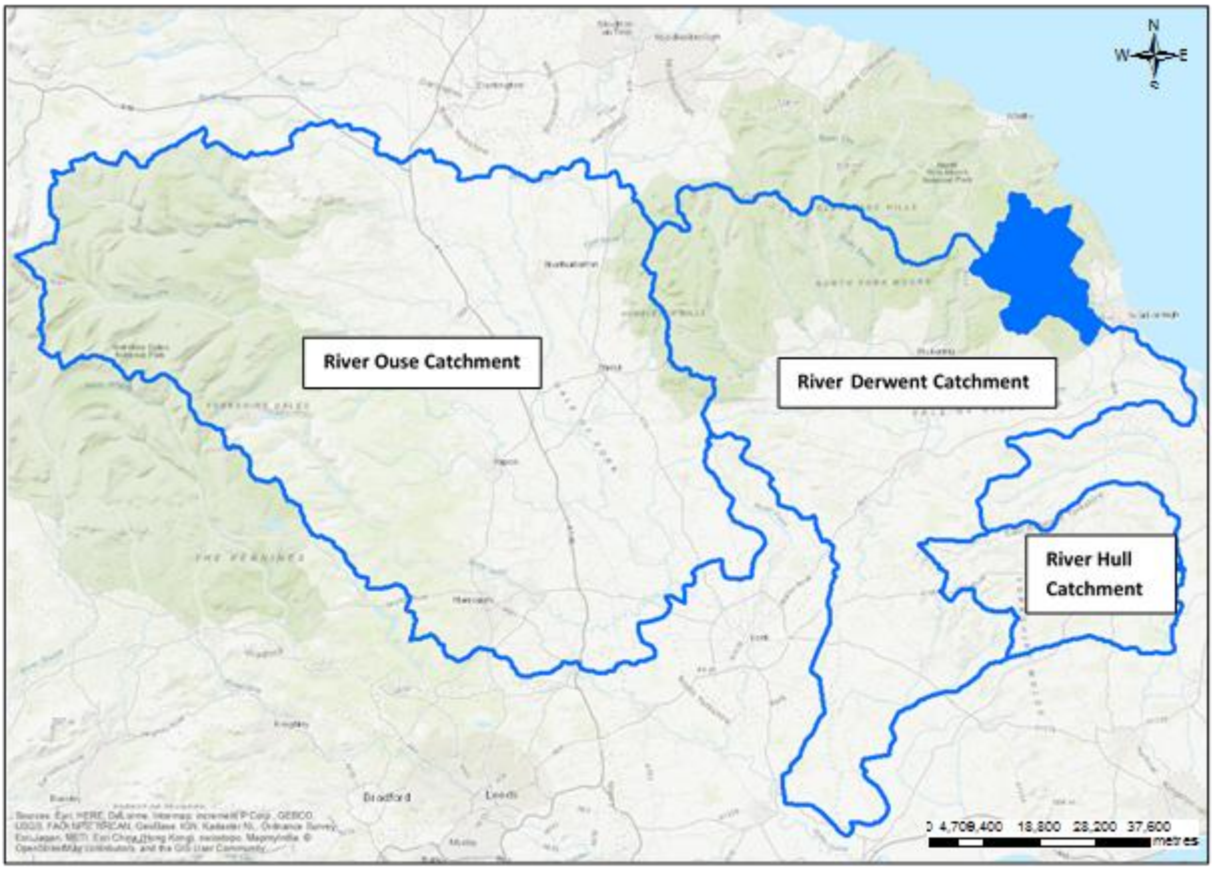


Figure. 19: Metaldehyde high risk river catchments.

Monitoring for metaldehyde was established in 2009. The table below shows the number of exceedances of the pesticide standard across our region since 2009.

Table 9: Number of metaldehyde failures by year since 2009.

	2009	2010	2011	2012	2013	2014	2015	2016
Total	18	1	6	33	2	15	9	8

In March 2017, we provided reports to DWI highlighting our progress toward achieving compliance with the pesticide standard. In the reports, we discussed a payment for ecosystem services (PES) solution, this applied to a relatively small area in the North-East corner of the River Derwent catchment (shaded blue in Figure 19). This approach was readily adopted by the farming community and they are continuing to participate in this solution. We have identified that abstraction control and source selection provides a potential solution for the medium size abstraction from the River Hull. The degree of success for these approaches will be evidenced by the end of December 2017 once crops are established and the slugs no longer active.

The challenge remains to manage metaldehyde risk in the large river catchments. The graphs below suggest that progress is being made against the peak in 2012.

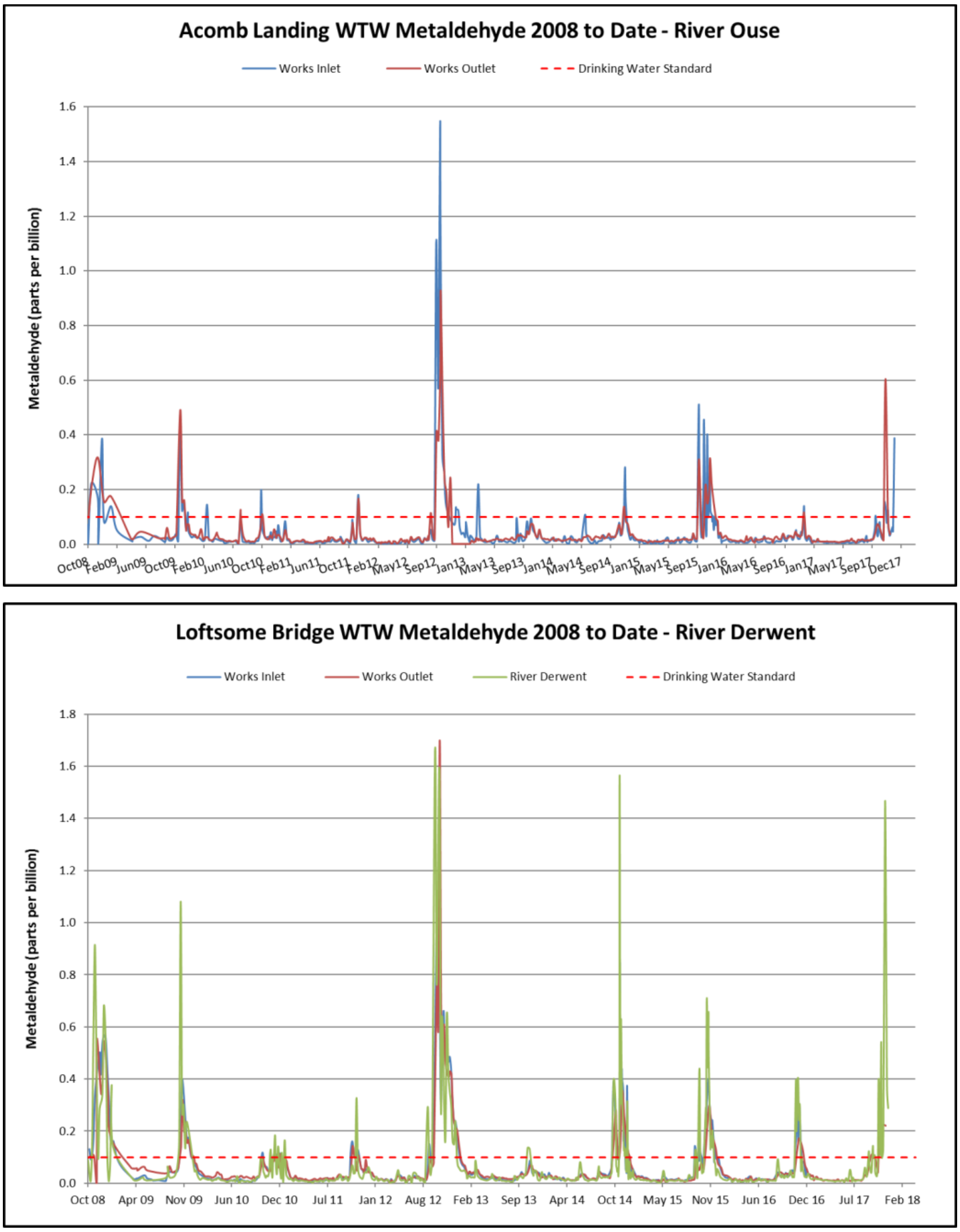


Figure. 20: Metaldehyde trends from the River Derwent and River Ouse.

We do not propose making any proposals to DWI to install treatment at any sites within AMP7 to address metaldehyde. We have researched and costed two viable solutions for those sites which remain at risk. These are based on high rate PAC dosing or, as an alternative, the use of ultra-violet (UV)/peroxide based treatment. We do not believe that ozone based technologies are feasible due to the relatively high levels of bromide in the waters concerned.

We are developing proposals within WINEP to scale up the activities undertaken as investigations during AMP6 into new sub-catchments. We are applying more intensive approaches in these and the existing sub-catchments identified as high risk.

The key activities identified are:

- The continued employment of Catchment Sensitive Farming Officers through Natural England.
- The deployment of additional Catchment Sensitive Farming Officers resource by YW.
- Development of more granular risk mapping and GIS tools to maximise impact of Catchment Sensitive Farming Officers.
- The development predictive techniques for our Service Delivery Centre, to allow improved decision making relating to abstraction.
- Consideration of targeted PES schemes.
- Consideration of soil health advice to minimise the use of chemical control products in general and more specifically metaldehyde.
- Ways of driving best practice farming activities from the early adopters into the catchments.
- Working with the supply chain for arable products to promote metaldehyde free approaches.
- Developing an innovative system for the “loan” of equipment, which brings significant risk reduction into catchments as a means of driving the adoption of new slug control techniques into farming.
- More sustainable links with other catchment stakeholders such as the Rivers Trust and Yorkshire Wildlife Trust.

4.6 Other risks

4.6.1. Lead and plumbosolvency control

The lead risk within our region has been reduced and at present 99.6% of samples from an enhanced monitoring programme comply with the current standard at the customers tap of 10µg/l Pb. This has been achieved primarily by phosphate dosing across all areas of the network (with the exception of some very small areas of the network). This has been supported by lead pipe replacement where required. We have summarised below the approach we have taken in AMP5 and AMP6 to reduce the risk of lead exposure (full details can be found in Part B (Section 2.7).

Plumbosolvency control

We ensure that the conditions for optimal plumbosolvency control are achieved within the network by reviewing phosphate dosing and treated water pH. We recognise that industry best practice is currently based on relatively old research and that this needs to be refreshed. In AMP5 we undertook scoping research with Huddersfield University, this identified a number of potential areas of research that provided us with a better understanding of the links between bulk water chemistry, phosphate dosing, and potential lead concentrations, and the factors controlling the presence of particulate lead. This research is underway, with a post-doctoral researcher appointed at the University of Huddersfield. We expect the research to be completed by 2019.

Lead pipe replacement

For a number of AMP periods, the replacement or lining of communication pipes has formed the key approach to managing residual lead risk in those areas where plumbosolvency appears slightly less effective.

Lead pipe replacement & lining (AMP5)

In AMP 5, we undertook water supply system and distribution management area (DMA) level replacement or lining of communication pipes. This demonstrated some notable improvements in the presence of lead in the water from pre and post intervention sampling. The pre-data for WSZ replacement and lining showed that 6% of samples were above the regulatory limit of 10ug/l. By comparison, only 0.4% of samples were above that level in the post-data. Considerable improvements have also been observed in the maximum figures (128µg/l compared to 13.2µg/l) and the average figures (2.75µg/l compared to 1.19µg/l).

Lead service pipe lining trial (AMP6)

In our AMP6 large scale pilot, lead service pipes were lined for circa 1000 social housing properties in Rotherham Metropolitan District Council's area. This provided us with the opportunity to understand both the logistics and potential benefits of this approach.

In total, 987 service pipes were lined and 16 service pipes were renewed. Pipes were renewed where it was not technically feasible to carry out the lining. 79% of the properties were council owned and 21% were privately owned.

To assess the results of this service pipe lining trial, 95 houses, located in 16 streets, were samples, pre and post rehabilitation. The results show clearly that there are lower concentrations in the lead in the post lining sample results, with the highest quality of water being observed post-lining and following a 3-minute flush. The sampling also confirmed that the greater the proportion of lead pipe that is remediated the greater the improvement in water quality delivered. As it is generally the last 8m of pipe which has the greatest influence on the compliance sample, and potentially therefore the lead consumption of the household, the remediation of the service pipe has demonstrated greater benefits to customers than the remediation of the communication pipe only.

Plans for AMP7

As this submission precedes the development of the long-term strategy for lead we believe that it is appropriate to pause widespread communication pipe lining or replacement, and to undertake more targeted activity during AMP7. This is detailed in Part B – Section 2.7 Lead

4.6.2 Customer acceptability - discolouration

We have made significant interventions over the last 20 years which have had a direct impact on discolouration performance. These are:

- 1996 – Investment in discolouration began (target only >= 10/1000 in WSZs initially).

- 1998/99 – Work Authorisation Notes Database (WAND) process began.
- 1999 – Water treatment works improvements began.
- 2000 – AMP3 Section 19 investment started (target = 4/1000 in WSZs)
- By 2010 – Section 19 programme materially completed.
- 2010 – DOMS implemented (The PR09 target was to maintain a regional rate at 4/1000 properties).
- 2015 – Comparative performance commitment required further reductions in discolouration contacts, resulting in a risk based approach to managing discolouration.

The graph below compares discolouration investment and performance. It demonstrates an improvement in performance since 2001. The Section 19 capital programme was aimed at a step change in improvement of the quality of the water our customers receive. The focus was on main renewal and rehabilitation and accordingly had comparatively high levels of associated investment. In AMP5, investment levels have been reduced, but performance has continued to improve. This performance improvement was due to targeting activity in the right areas of the network, along with addressing the risk of discolouration from trunk mains.

During AMP6 our approach has changed. The adoption of a totex based approach has driven us to think and act differently in order to drive the continued reduction in discolouration complaints. Activity completed in AMP6 to date, has been a combination of innovative activity in the form of a large uniform DMA flushing programme, and the introduction of trunk main conditioning techniques, supported by a reduced level of traditional rehabilitation and renewal activity.

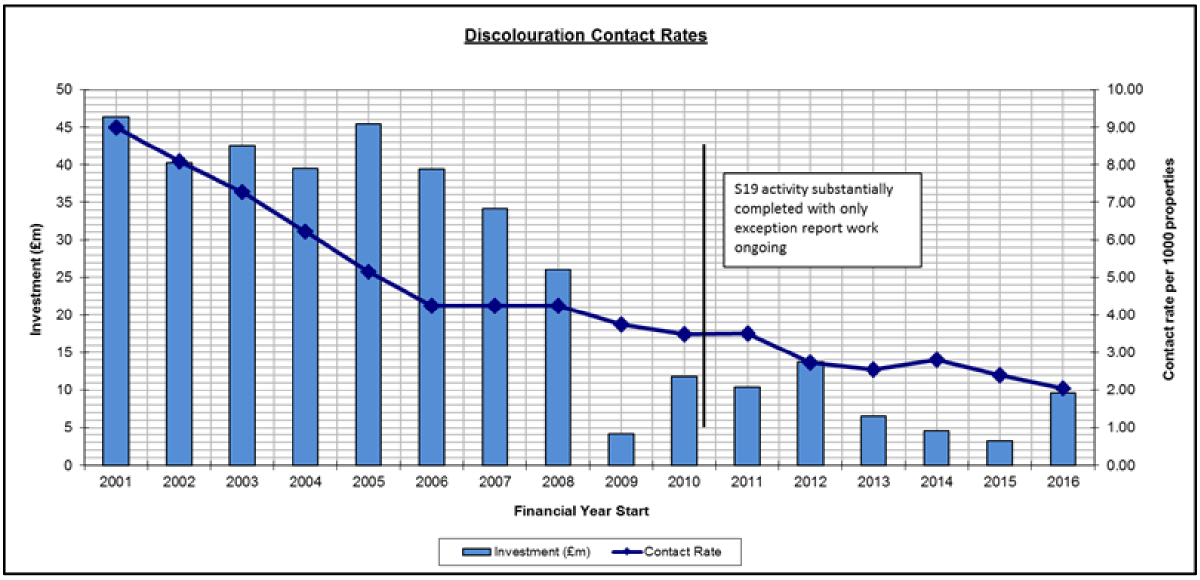
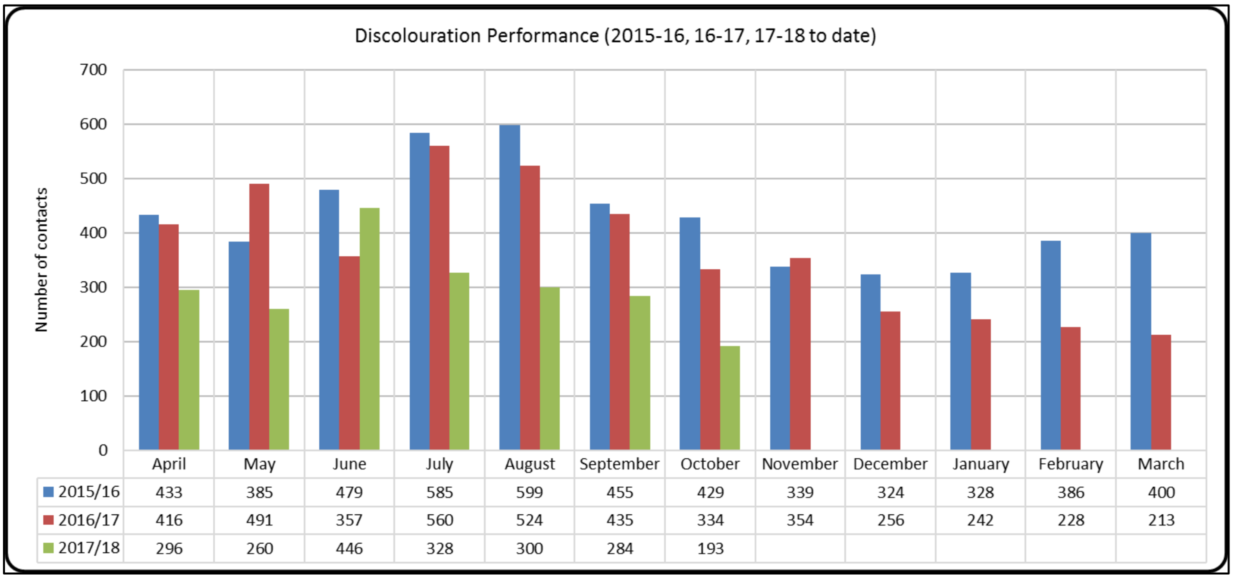


Figure. 21: Discolouration investment and performance.



	April	May	June	July	August	September	October	November	December	January	February	March
2015/16	433	385	479	585	599	455	429	339	324	328	386	400
2016/17	416	491	357	560	524	435	334	354	256	242	228	213
2017/18	296	260	446	328	300	284	193					

Figure. 22: Comparative monthly discolouration performance 2015/16 to date.

Innovative interventions to reduce discolouration (AMP7)

Uniform flushing

The objective for AMP7 is to continue to evolve our uniform flushing programme, which is an innovative enhancement of a traditional approach. The aim is to base our AMP7 uniform flushing programme, on a proactive risk based approach to the reduction of discolouration events. Due to the instrumentation utilised during the flushing process, we have the ability to calculate sediment depths within mains. This enables us to model and predict which DMAs are likely to cause discolouration should the displacement of deposited material occur from a flow increase. By understanding this "discolouration potential" we will be able to drive our discolouration performance down to lower levels. The information that we collect through the uniform flushing process is then available to drive long term plans for network rehabilitation. It will replace the dependence on customer contacts as a surrogate for network condition and performance. We will discuss this approach in more detail within our long-term strategy document.

Uniform flushing – Approach

- **Full DMA uniform velocity flushing.**
  - Systematically working from the inlet, valving off individual pipe lengths and flushing every pipe to achieve 2 turnovers at a specific velocity .
- **24 full time flushing teams.**
  - 80+ DMAs per month.
  - 1/3 of our network every year.
- **A full DMA service check.**
  - Identifying shut valves.
  - Capturing valuable flushing information.

Trunk main conditioning

Our approach to addressing discolouration risk from our large diameter mains will be to carry out trunk main conditioning. Where it is possible to do so, this will be automated. We have trialled this approach in AMP6 and aim to roll this out on a much larger scale throughout AMP7. The approach will give benefit by reducing the risk of large scale 'one off' incidents', as well as reducing the amount of sediment transferred from our trunk main system into the DMAs. Once the material is in a DMA, there is a risk that should it mobilised it could result in an impact to customers.

Automated trunk main conditioning – approach.

- **Automated trunk main conditioning.**
  - Identify mobilisation potential when flow increases occur.
  - Build single pipe PODDS models for identified high risk pipe lengths.
  - cyclical reconditioning operations are designed to increase the safe operating flow as part of an asset care plan.
- **Manual trunk main conditioning.**
  - Field teams will manually condition trunk mains where it is not possible to automate.
- **A full water balance calculation** can be applied once sufficient telemetry and instrumentation has been installed.

Future planning to reduce non-compliance and contacts due to discolouration

We believe that pursuing the combination of these approaches will deliver a significantly improved performance over AMP7, and provide the data to truly understand the condition of the network in much greater detail than has been previously possible with regard to regeneration and deposition rates.

AMP 7 proposals

We intend to continue and refine the above approaches as the means of further improving customer acceptability of supplies and compliance.

We have not made a submission of specific network schemes for support by DWI. We include the details in this section to demonstrate our commitment to making continued, significant improvements in this key area of performance.

Case Study – Rusby Wood Automated Trunk Main Conditioning

Rusby Wood Water Supply System is fed from Ingbirchworth WTW and supplies 50 DMAs and 21981 properties in the area North West of Barnsley, South Yorkshire.
The historic discolouration performance in this area has been poor. The worst performing year for discolouration in this water supply system (WSS) was in 2010 where 390 discolouration customer contacts were recorded. This equates to a contact rate of 17.74 contacts/1000 properties. The contact rate in the WSS for the 12 months to 1st Sept 2016 is 5 contacts/1000 properties, however, this is well above the target of 1.5 contacts /1000 properties required to achieve the year 3 water quality performance commitment of 6108 contacts.

Flow Directional Cluster Analysis

Flow directional cluster analysis of discolouration customer contacts was performed on this WSS by dividing the WSS into 6 distinct transmission sections. Analysis of the period from January 2002 to August 2016 shows that there have been numerous trunk main mobilisation incidents.

Innovative Solution

We have built a fully automated (and fully visible within our RTS system) self conditioning WSS that applies the principles of PODDS modelling to minimise discolouration risk within this area. Within the 6 transmission sections each service reservoir has had the relevant telemetry installed (valve, flow meter, turbidity meter, PLC, booster, non return valve, pressure transducer) to allow it to understand flows, pressure and reservoir levels in order to automatically increase flows at the right times to allow sufficient conditioning of the trunk mains in order to reduce discolouration risk.
The scheme will be fully visible on RTS, and will cyclically cleanse the trunk mains system monthly.

Appendix 1: References from Leeds University Review of Yorkshire Peatlands

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PR19 – Yorkshire Water's submission to DWI

Part B – Parameter specific risks & site-specific proposals

22nd December 2017

Contents

Within Part A of this document we identified the background to this submission in terms of the Company's current performance, the risks it perceives now and into the future, and where it seeks the support of DWI in their resolution.

This part of the document is based around the resolution of risks associated with deterioration in raw water quality, along with maintaining progress in reducing the risk from lead pipes.

1.0 Our Proposals to Resolve Key Raw Water Quality Risks

There are a number of water quality risks which are largely driven by deterioration within the catchments of Yorkshire:

- DBPs (Disinfection by-products) (colour) – due to deterioration in peatland associated with upland impounding reservoirs – and is the most significant risk which the Company is exposed to.
- Nitrate – primarily due to use of fertilisers on arable soils.
- Customer acceptability (algae) – driving customer acceptability risks.
- *Cryptosporidium* – potentially due to increased wildlife activity – indicating the potential for future risk to health.
- Metaldehyde – as a result of its use to protect arable crops – a current and potential future compliance risk.

Table 1: Summary table.

Site	Capex (£million)	Opex per annum (£million)
Tophill Low WTW	£ 16.3	£ 0.4
Chellow Heights WTW	£ 23.9	£ 1.1
Embsay WTW	£ 8.0	£ 0.1
Fixby WTW	£ 5.6	£ 0.04
Sladen Valley WTW	£ 14.6	£ 0.2
Oldfield WTW	£ 6.1	£ 0.1
Lead Pipe Replacement	£ 15.0	£ 0.0
Total	**£ 89.8**	**£ 2.0**

1.1 Colour / DBP Risk – driven by deterioration in upland coloured waters

Our AMP6 catchment management programme was driven by long term water quality risks identified through our Drinking Water Safety Plan Risk Assessments, and Safeguard Zone Action Plans for Drinking Water Protected

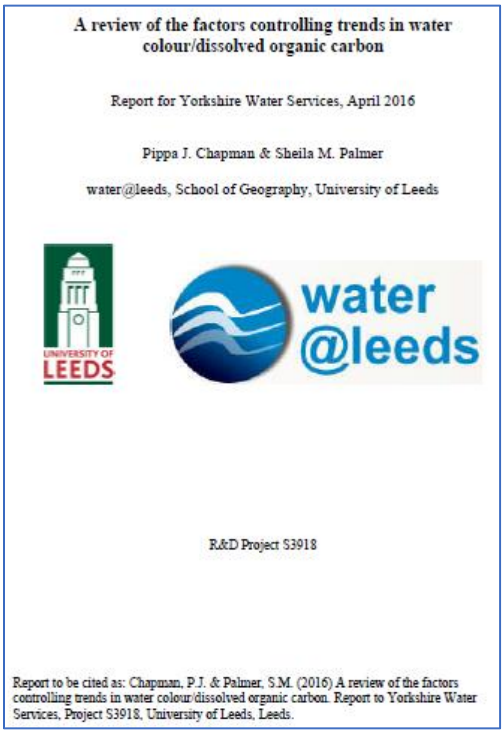
Areas enabled by the Environment Agency (EA), through the National Environment Programme. Our programme of investment has been informed by experience of the AMP5 catchment management pilot scheme and further Research and Development throughout AMP6. Our catchment management programme is a key component of delivering our vision of 'Taking Responsibility for the Water Environment for Good' and our strategic business objective to deliver 'Excellent Catchments, Rivers and Coasts".

In developing our proposals for PR19 we have followed similar processes to previous reviews. We have looked at sources where deterioration in raw water is continuing, and where this causes the levels of dissolved organic carbon (DOC) to approach the limits of treatability for the installed processes. We then assess when such thresholds may be crossed and, for example, a DBP risk could materialise.

1.1.1 Action based on research

During AMPs 5 & 6 we have invested in significant research in this area of risk to raw water quality, mainly with the School of Geography at Leeds University. The key foci of research have been deepening our understanding of the drivers which impact on the generation of colour/DOC from peatland soils in the uplands, and, gaining a better understanding of cause and effect for the range of remedial activities which could be deployed to mitigate the deterioration.

1.1.1.a Research Report: - A review of the factors controlling trends in water colour/dissolved organic carbon


A review of the factors controlling trends in water colour/dissolved organic carbon

Report for Yorkshire Water Services, April 2016

Pippa J. Chapman & Sheila M. Palmer

water@leeds, School of Geography, University of Leeds

R&D Project S3918

Report to be cited as: Chapman, P.J. & Palmer, S.M. (2016) A review of the factors controlling trends in water colour/dissolved organic carbon. Report to Yorkshire Water Services, Project S3918, University of Leeds, Leeds.

The report "A review of the factors controlling trends in water colour/dissolved organic carbon" – April 2016 concludes: - "Key drivers of change in DOC quantity & quality - Based on long-term observational data, most studies in Europe, which previously experienced high loads of sulphur (S) deposition, have identified recovery from acid rain as the main driver of DOC trend. This has led to theories of solubility control mechanisms on DOC that have since been supported by field and laboratory experiments. In the UK, S deposition declined by 80% between 1986 and 2006 to 1 Mt SO_2 yr-1. By 2021, a further 50% reduction in SO_2 deposition is expected. It might therefore be expected that no further increase in surface water DOC concentrations, as a result of this mechanism, is likely given that S deposition has reached such low levels.

However, peat and organo-mineral soils have accumulated large amounts of deposited S in organic and inorganic binding forms over the last 100 years. This S is likely to be oxidised to SO_4 during droughts leading to episodic acidification of soils and a reduction in surface water DOC followed by a potential increase in DOC once the drought has passed." "Statistical models have proved invaluable in identifying possible key drivers of long-term DOC change and to a limited extent in quantifying the contribution of individual drivers. Process-based models have a predictive capacity and allow scenarios to be run that mimic expected changes in identified drivers such as acid deposition, climate and possibly land management, and can also allow for between-catchment differences in soil type. They have advantage over statistical models in that they are based on current understanding of process and can incorporate soil controls on DOC production, hydrology and chemistry as well as in-stream processes such as UV-degradation and biotic cycling. It should be remembered that more than one driver may be occurring at the same time and interacting together to lead to a change in surface water colour/DOC concentration. So, while a national or regional survey may show S deposition or climate change as the main driver of the trend in water colour/DOC it doesn't mean that at the catchment scale you can't have land management also impacting on top of (and interacting with) the S deposition and climate effects. Hence land management may also have a role in either increasing or decreasing surface water colour/DOC concentrations. It is envisaged that the modelling analysis that we undertake in the second part of this project will highlight the possible effects of land management versus no intervention on the DOC trend in light of climate and S deposition effects. It should also be noted that most studies to date have focussed on changes in DOC quantity rather than quality. Thus, more research is needed on how the three main drivers have affected DOC quality in addition to quantity."

This report was followed by a further piece of research which attempted to identify what may be driving more acute deterioration in the Yorkshire Region than is apparent in other regions of the UK – Future Trends in Water Colour: The role of regional drivers – May 2017.

The Executive Summary states: -

"This project has investigated (i) the rate of increase in water colour at specific water treatment works (WTW) across the Yorkshire region; (ii) the rate of change in regional drivers of water colour change, such as temperature, rainfall and sulphur deposition, and (iii) used a statistical modelling approach and a process model to predict future trends in water colour based on future predicted reductions in sulphur deposition and changes in temperature and precipitation.

Key findings and recommendations are provided below.

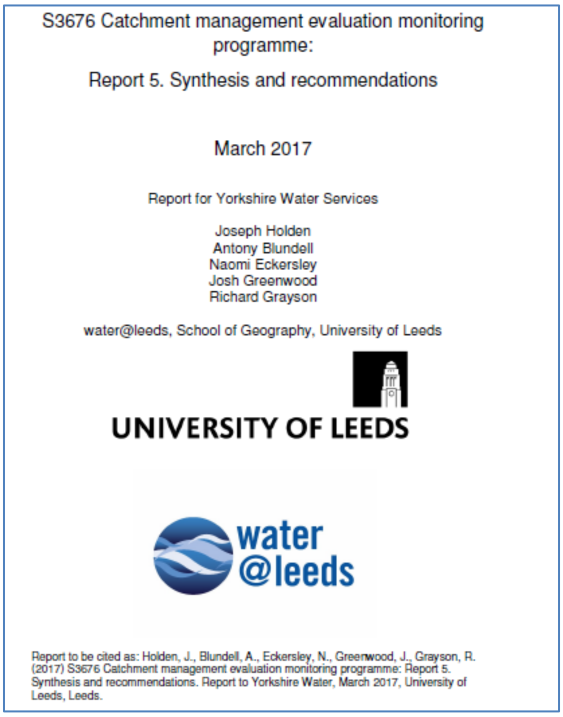
- Over the period 1987-2015, water colour increased significantly ($p<0.01$), by between 1.5 and 4.9 Hazen/year, at 10 of the 11 sites. In contrast, over the period 1998-2015, water colour only increased significantly ($p<0.05$), by between 0.5 and 1.4 Hazen/year, at 6 of the 14 sites. This shows that the greatest rise in water colour occurred between 1987 and 1998.
- The trend analysis also shows that the maximum water colour recorded in each year has significantly ($p<0.05$) increased at 10 of the 11 sites over the period 1987-2015, by between 2.0 and 7.2 Hazen/year. This has important implications as the WTW has to be able to treat these waters with high water colour. In contrast, only Agden showed a significant ($p<0.\ 05$) increase in maximum water colour over the period 1998-2015. This reflects the fact that maximum water colour was very high in 1998 at most sites, following the drought of 1996, which was the major influence on most other sites.
- Water colour was suppressed at all sites during the drought of 1995 and for several years following the drought (1996 & 1997) before increasing to very high-water colour values in 1998. Although droughts will continue to have an impact on water colour in the future, it is unlikely to be as pronounced as that observed following the 1995 drought, which was a 1 in 200-year event and coincided with a period of rapid decline in sulphur deposition.

- Over the period 1988-2014, DOC concentrations in the River Etherow (a site in the Upland Waters Monitoring Network), which flows into Woodhead reservoir, Peak District, increased significantly ($p<0.001$) and annual concentrations have increased by 65% from 3.8 to 10.9 mg L-1. In addition, a significant ($p<0.001$) negative relationship was observed between stream water DOC and SO_4; as SO_4 concentrations have declined DOC concentrations have increased.
- No trend in regional annual mean daily maximum air temperature or total annual rainfall was observed over the period 1987-2015. However, standardising the rolling 5-year means as Z-scores show (i) the trends in temperature are consistent at both locations (Bradford and Sheffield) and display an increase over the long-term mean (Z-score>0) (Z-scores indicate whether particular observations are above or below the mean of all observations) throughout much of the 1990s and 2000s, but with a marked decline around 2009; (ii) the annual rainfall trends at Gorple and Redmires both show an oscillation on an approximate 15-20-year cycle, with peaks in the late 1960s, early 1980s, and early 2000s.
- Seasonal rainfall patterns were explored by comparing the total summer and total autumn precipitation as Z-scores. At Gorple the autumn rainfall declined sharply from a high in the late 1970s (Z-score>2) and continued to be below the long-term mean (Z-score <0) to the end of the data record. In contrast, the summer rainfall at Gorple has increased sharply from a low during the mid-1990s drought (Z-score ≈1.5) to fluctuate above the long-term mean from 2000 to the end of the record. At Redmires, the autumn rainfall trend is dominated by high values in the mid-1990s (Z-score = 2.5). Since 2000, the autumn rainfall at both Gorple and Redmires has fluctuated below the long-term mean, whereas the summer rainfall has fluctuated above the long-term mean.
- Over the period 1987-2015, UK sulphur dioxide (SO_2) emissions and sulphate (SO_4) deposition at two sites in the Peak District (Wardlow Hay Cop and Etherow) have significantly ($p<0.001$) declined; SO_2 emissions by 94% from 3.8 to 0.24 million tonnes and SO_4 deposition by 60% at Wardlow Hay Cop and 76% at Etherrow.
- Standardising the rolling 5-year means of water colour as Z-scores has demonstrated that the long-term pattern in water colour is similar at seven WTW, regardless of their baseline colour, and must therefore be controlled by a regional driver. Colour was fairly stable through the 1980s, increased sharply from around 1990 to about 2007/8, and thereafter appears to have stabilised, although there is considerable inter-annual variation.
- Using linear regression modelling where multiple drivers were considered together, the most successful models in predicting colour Z-score over the period 1987-2015 were those that included SO_2 emissions and summer rainfall; explaining 88-97% ($p<0.001$) of the long-term trend in colour.
- Summer rainfall and SO_2 emissions were also successful, but to a lesser extent, in explaining colour variation over the period 1998-2015 at most sites (r2= 71-96%, $p<0.001$ at 5 sites). The notable exceptions were Langsett and Ewden, where the best models explained only about 50% ($p<0.01$) of the long-term variation in colour. This suggests that another driver that was not included in the linear regression model has contributed to a change in colour at these sites during the last two decades, such as changes in land management (e.g. increased heather burning).
- Multiple regression modelling of Z scores for annual averages of water colour at Keighley Moor showed that 84% of the variation in trend was accounted for by declining SO_2 emissions and increasing summer rainfall. This equation was then used to predict water colour in the future (see 12).
- Predictive modelling for Keighley Moor, using realistic scenarios of future SO_2 emissions and summer rainfall, demonstrated that water colour is likely to stabilise in the period to 2030, with predictions for the wettest

summer rainfall scenarios (50-year and 100-year events) delivering annual mean water colour that is similar to that observed for the wettest year on record (2012 annual mean = 172 Hazen).

- INCA-C predicted that mean monthly DOC concentrations at Oldfield WTW – Keighley Moor Inlet would be similar to those observed for the period 2010-2015 in the 2030s and between 20 and 24% higher by the 2080s in response to changes in SO4 deposition and climate change scenarios. (INCA-C is a model used to predict the impact of a range of climate, weather, atmospheric and other variables on the production of DOC (colour) by peat catchments). Minimum concentrations are projected to be similar in the 2030s and 2080s to those observed during the period 2010-2015. Projected maximum concentrations in 2030 and 2080 fall within the envelope of DOC concentrations observed in the 'recent past (2010-2015)' for the months June-October. However, the scenarios suggest that maximum concentrations will be 5 and 10 mg/L higher than the recent past in the 2030s and 2080s, respectively, (which equates to 20-30% and 45-50% higher) in the months January to May. However, all projected monthly maximum concentrations in 2030 fall below within the envelope of maximum concentration observed over the period 2010-2015.
- Both models (statistical and processes) show that the biggest increase in DOC/water colour was observed in the 1990s, as a result of declining SO_4 deposition which led to an increase in soil pH and therefore an increase in DOC solubility.
- Both models suggest that DOC/water colour (annual and monthly mean concentrations) will be similar in 2030 as they have been in the period 2010-2015, and that in the future climate change, in particular wet summers, will have a bigger impact in controlling DOC/water colour.

1.1.1.b Research Report: - Review of Catchment Management Activity; site monitoring data


S3676 Catchment management evaluation monitoring programme:

Report 5. Synthesis and recommendations

March 2017

Report for Yorkshire Water Services

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Report to be cited as: Holden, J., Blundell, A., Eckersley, N., Greenwood, J., Grayson, R. (2017) S3676 Catchment management evaluation monitoring programme: Report 5. Synthesis and recommendations. Report to Yorkshire Water, March 2017, University of Leeds, Leeds.

In addition to the above reports which looked at modelling future risk of increasing colour/DOC, we also commissioned Leeds university to undertake a review of the monitoring data. The data has been collected from our catchments where we and others have undertaken interventions, aimed at remediating the areas of catchment perceived as deteriorated.

The report: "Catchment management evaluation monitoring programme – Report 5: Synthesis and Recommendations" – March 2017, was commissioned in preparation for the making of this submission to the Inspectorate, and the inclusion of activity within Water Industry National Environment Programme (WINEP) – to be agreed with the Environment Agency.

"This report brings together findings from the Oldfield, Longwood and Chellow catchment monitoring schemes. The report links these findings to other catchment solutions work undertaken by water@leeds both for Yorkshire Water and for other organisations, and the upland literature more generally, in order to highlight key recommendations for the business".

Summary findings from the monitoring programme

The study examined data from seven peatland restoration sites collected up to the end of December 2016. While data has been collected under the current contract since July 2015, we also amalgamated and analysed earlier data from the study sites collected as part of our investigation. The length of these datasets varies depending on the site, but in the case of Keighley Moor, the data period goes back to November 2008 which pre-dates any peatland restoration work. For the other catchments, the monitoring programme is shorter and in some cases peatland restoration works have only recently (e.g. in 2015) been completed. Using control catchments, we have attempted to determine which water quality effects have been driven by inter-annual changes in weather conditions / seasonal climate, and which have been driven by peatland restoration.

The key findings are:

- Grip blocking is the only restoration strategy studied for which there is strong evidence of it leading to reductions in DOC and colour in streams supplied by peat (compared to control systems without grip blocking). However, not all streams with grip blocking upslope show these reductions.
- The nature of gullies and the types of gully blocking that have been adopted on the study catchments means that, in general, gully blocking has been ineffective for DOC and colour reductions.
- However, for the few cases in which gully position in the landscape and the gully blocking style adopted meant that full ponding of water in the gully could occur almost flush with the surrounding peat surface, then water tables were successfully raised in the nearby peat and DOC and colour production were significantly reduced.
- At many sites, there appears to be a control of vegetation cover on DOC and colour with moor grasses associated with lower colour, and shrub vegetation (e.g. heather) associated with higher colour. Therefore, long-term change in vegetation should be pursued in our catchments.
- There has been a long-term shift in the ratio of humic and fulvic acid components of stream water colour. This is not an effect of land management, but a more general trend.
- There has been a shift in the ratio of colour and DOC concentrations (higher SUVA254) at some sites in response to management interventions. This may be a first sign of interventions such as re-vegetation starting to take effect, in advance of colour reductions. Where gully blocking at some sites has increased gully edge water tables during wet periods, but the water tables still drop substantially during drier periods, then SUVA254 has become more variable in source waters.
- At Keighley Moor, there was a significant difference (95 % significance level) in DOC and colour at the Oldfield WTW compared with those in the stream waters feeding the reservoir. We found generally lower DOC and colour in the WTW than in streams suggesting some of the DOC and colour is transformed in the system by reservoir turnover and also possibly by dilution from groundwater sources feeding the reservoir. However, the timing of peak colour was prolonged in the WTW into late winter, well after the peak had occurred in the streams.
- Importantly, during years with relatively small amounts of summer and autumn rainfall, colour was greater at Oldfield WTW relative to two of the three main Keighley Moor Reservoir Catchment streams that contribute to the reservoir. The intake pipes and reservoir are a potential source of colour during these drier years.
- Some upland peat systems also have deeper groundwater inputs to streams which are associated with low DOC and colour. These streams become more important during drier periods but also mean that expected

reductions in DOC and colour from land management are not always as expected depending on the local hydrological situation.

- There was evidence that the effects of managed burning and consequent heather re-establishment on poor water quality last for several years after burning with enhanced DOC and colour compared to nearby areas with similar water table conditions.
- Some streams, in whose catchments a lot of heather brash or heather bales have been used as part of peatland restoration, have shown recent (during 2016) signs of enhanced DOC and colour compared to control streams."

1.1.2 Assessment of colour (DBP) risk

Yorkshire Water operates around 130 Impounding Reservoirs which are generally on the Eastern Slopes of the Pennine chain. As a part of the development of our approach for PR19 we have assessed all sources, either at the asset level – for strategic sources, or at the reservoir group level – for less significant sources, to understand the trends in raw water quality.

We have typically reviewed raw water quality data from 1990 to date and an example of typical plots and analysis are given in Figure 1.

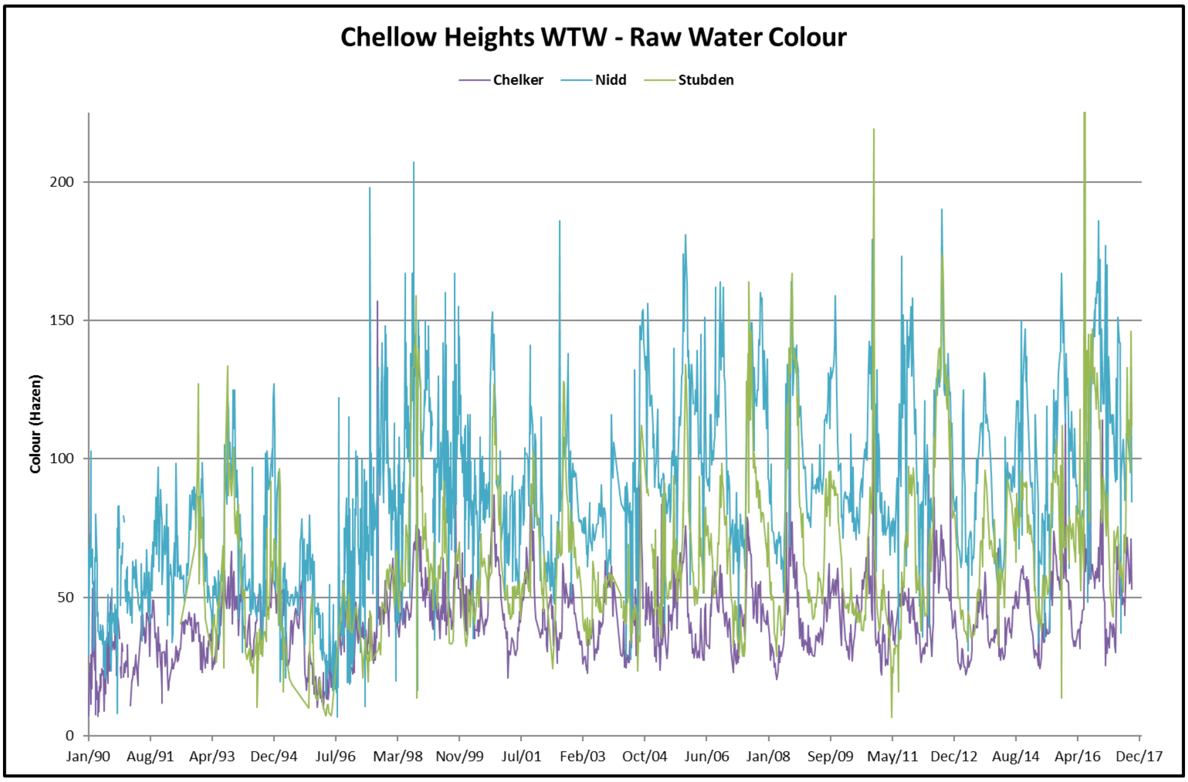

Figure. 1: Typical raw water trend for colour (Chellow WTW sources shown).

Where sites have exhibited deterioration, the data sets have been subject to statistical analysis to test the significance of the deterioration; this activity was undertaken by our own statisticians in partnership with statisticians from Leeds University.

Table 2: Example of statistical analysis for colour deterioration

	JAN 1998+							
	By MONTH				By YEAR			
Site	Max	Mean	Median	Min	Max	Mean	Median	Min
Chellow Heights Chelker	-0.321	-0.244	-0.244	-0.13	0.311	-0.176	-0.142	-0.1
Chellow Heights Nidd	-0.282	0.339	0.214	0.992	-0.833	-0.199	-0.121	1.83
	JAN 2004+							
	By MONTH				By YEAR			
Site	Max	Mean	Median	Min	Max	Mean	Median	Min
Chellow Heights Chelker	-0.12	0.096	0.179	0.39	-0.047	0.129	0.322	0.602
Chellow Heights Nidd	-1	-0.847	-0.938	-0.665	-1.414	-0.971	-0.841	1.684
KEY:	Highly sig (@1% level)	(@ 5% lev	Non sig					

1.1.3 YW Action Plan based on research and data analysis

Based on the evidence from this and other associated research we are actively planning with both Leeds University and the Environment Agency, to identify the scope of activity that is required to begin to halt the deterioration in water quality from peat based catchments. One key area of debate is around the need for multiple interventions on peatlands to secure conditions which protect water quality for the long term.

Put simply, much of the activity undertaken in the current and previous AMP periods can be viewed as "repairing the hydrology" of the catchment. For Catchment Management (CM) to be a long-term solution there is a need for a second phase of "restoring a functioning bog community, dominated by Sphagnum sp.". We are working with the EA to ensure that this approach is fully supported within the WINEP.

We assessed all sources where evidence exists of raw water deterioration and estimated the future dates when this would lead to a risk of failing drinking water quality standards, as a means of determining whether treatment, catchment, or a combination provided the appropriate solution.

If this analysis suggest that failure would occur before mid to late AMP8 then a treatment solution has been proposed; where failure is indicated beyond AMP8 then we are proposing catchment intervention only within AMP7. Where treatment is proposed, this will be supported by catchment management to enhance the sustainability of the solution, and limit future OPEX requirements.

1.1.4 Choice of solutions

Our approach to managing colour risk follows that adopted previously, a twin-track integration of treatment and catchment solutions, unless the risk is such that catchment management has the opportunity to reduce the hazard and avoid the risk becoming material.

1.1.4.a Catchment Management and the WINEP Programme

We recognise the need to improve the upland catchments of Yorkshire, those we own, and those owned by others, as the most appropriate means of preventing further deterioration in raw water quality.

Our AMP6 catchment programme was incorporated into the Environment Agency's National Environment programme (NEP). Our proposed AMP7 catchment management programme has been included by the EA within the WINEP-2 release; we are now working to develop the Scopes and costings needed to confirm the programme within WINEP-3. We have referenced our programme within this submission to keep the DWI aware of the activity as part of the mitigation of medium and longer-term Drinking Water Safety Planning (DWSP) risks.

Our catchment management programme will be implemented primarily through Water Framework Directive (WFD) mechanisms. The programme is based on the current Drinking Water Protected Areas designation; the existing identification of Safeguard Zones and the creation of Safeguard Zone Actions Plans with the EA. These Plans will be shared with a range of catchment stakeholders and Natural England (NE).

Our catchment programme covers a range of specific water quality parameters including colour, pesticides, nitrate and saline intrusion on reservoir, river and groundwater sources. It covers both implementation and investigations. The upland management schemes for colour will deliver a wide range of additional benefits to our customers and stakeholders, including flood risk attenuation, carbon mitigation and biodiversity. The programme will also contribute to resilience to climate change, as identified under our Adaptation Reporting requirement.

We consider that our catchment programme is consistent with specific guidance, or has support for the approach, from Department for Environment, Food and Rural Affairs (Defra), the EA, NE and the DWI.

1.1.4. b Treatment solutions

Where our assessment of the magnitude and timing of future risk has indicated treatment, solutions are required we have identified three broad solution routes:

1. The construction of additional similar process units alongside the existing plant – essentially de-rating the process loading and bringing these back to design – an example would be the construction of additional rapid gravity filters to resolve additional particulate loads due to increased colour and coagulant entering the clarification stage.
2. The construction of additional "conventional" process units, following the existing process train – an example would be the construction of a second stage of filters to allow the better separation of solids from water prior to chlorination.
3. The construction of an additional "novel" process preceding or within the existing process train – an example would be the introduction of the MIEX process as pre-treatment before coagulation/clarification stage on an existing treatment plant.

The first two solution routes require no explanation, but will be developed where relevant within the individual scheme proposals; however, the use of MIEX remains unique to Yorkshire Water in the UK, although a few other companies with similar challenges are looking at ion exchange based processes for DOC removal.

1.1.4.c Miex ion exchange for DOC removal prior to coagulation

MIEX is an ion exchange resin that selectively removes DOC. There are alternative DOC selective resins available that could be used in traditional ion exchange fixed beds, however the resin size in fixed beds is typically in the mm range, for example, 1 to 2 mm to avoid excessive head loss through the bed (in contrasts MIEX resin is 180µm in diameter). The larger particle size results in relatively low surface area and slow kinetics, thus a large resin inventory and large pressure vessels are required. For this reason, historically ion exchange for DOC removal has been costly and not favoured.

MIEX is a small diameter resin, around 180µm in diameter, that is applied in a stirred contactor which disperses the resin beads to ensure maximum surface availability. Along with its small diameter, it has a porous structure which increases the surface area available for exchange, so enables an ion exchange plant to be designed with a small footprint. The iron core of the resin means that under a magnetic field the particles agglomerate rapidly into fast settling particles that can be separated rapidly for regeneration. The MIEX process was initially evaluated in the UK in the mid-2000s as part of a Tailored Collaboration Project funded by American Water Works Association Research Foundation (AwwaRF) and collaborating water companies Yorkshire Water, Severn Trent Water and Thames Water. The project was initiated in response to the elevated levels of DOC that were starting to be seen in the late 90s and the operational and compliance problems caused by these elevated levels. Subsequent research and pilot trials, which we funded, resulted in three MIEX plants being built in Yorkshire in AMP4. Some years on, MIEX has been selected again as the preferred solution for one site during AMP6 and potentially a further 3 ion exchange processes installed during AMP7.

With conventional treatment high DOC water causes a number of problems at WTWs:

- It increases the solids load passing forward onto the existing process units, many of which were designed with a raw water envelope significantly lower than seen today.
- The nature of the DOC results in a weak floc structure, very susceptible to shear forces present within subsequent clarification and filtration processes, resulting in high clarified and filtered turbidity; so much so that at times of high colour the only solution is to restrict works throughput to maintain quality; this puts significant challenges on the company's supply demand balance.
- In addition to the throughput issues, when this high DOC occurs in the summer and autumn, the residual DOC after treatment can reach a level which leads to elevated disinfection by-product formation.

The MIEX process addresses all these issues.

- It is located at the inlet to the WTW, where it reduces the concentration of DOC, up-stream of the existing treatment processes, effectively bringing the raw water DOC closer to the original design envelope for coagulation/clarification.
- It selectively removes fractions of DOC in the mid to low molecular weight (MW) (<5 kDa) and is very effective at removing the lower MW (<3 kDa) organics known to be difficult to remove by coagulation. Coagulation is highly effective at removing the higher molecular weight >5kDa material. Thus, a combination of both MIEX plus coagulation gives an overall enhanced removal of DOC.

- This enhanced DOC removal reduces the solids load going onto the existing processes, enabling full throughout to be maintained under all raw water conditions. The removal of a specific fraction of DOC results in a stronger floc, more resistant to shear
- It gives enhanced removal of THM precursors, thought to be associated with the lower molecular weight fraction that coagulation does not target.
- It doesn't require the abandonment of existing processes

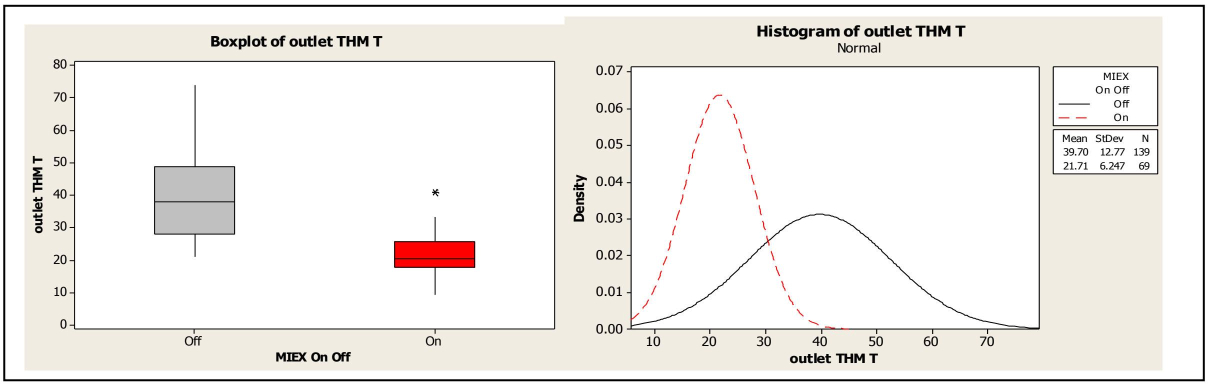

Figure. 2: Impact of MIEX pre-treatment on THM formation.

It is the combination of these benefits which gives MIEX the advantage over other solutions. In addition, some parameters of MIEX treatment are capable of significant modulation, which allows the degree of treatment to be matched to the raw water risk (DOC/colour). In particular, the ratio of flow through / to bypass flow - can be varied, and the regeneration rate of the resin adjusted. This allows for a very flexible enhancement to treatment and reduces the cost and environmental impact when intensive treatment is not required. This is very different, for example, to the option of using granulated activated carbon (GAC) as a DOC scavenger before chemical disinfection. Due to the long lead times required to regenerate GAC the capability has to be available at all times, in order that it remains effective when the raw water quality deteriorates.

1.1.4.d Further Development of this approach

Since the three plants were built in Yorkshire during AMP4 there have been two enhancements to the MIEX process which make it more effective and efficient.

- A new resin has been developed, with slightly large pores, designed to specifically address the issue of high molecular weight DOC inhibiting access to the porous structure.
- A high rate contactor has been developed which combines the mixing and separation elements in a single vessel, the benefit of this is a significantly smaller footprint, less civil work for large systems (concrete designs), and the opportunity to use pre-assembled skid mounted systems.

We are currently constructing a MIEX plant in Yorkshire that has taken advantage of these two developments. This site will be operational prior to the design activity being started for AMP7 solutions, which gives confidence in the potential solution.

We are planning research and development activity in the next 2 years to identify whether other similar technical solutions are available, so that we are able to investigate their feasibility in sufficient time to give design choices for AMP7 schemes.

1.2 Nitrate

Nitrate is not seen as a significant future risk for Yorkshire Water, the blending and treatment solutions which were implemented over the past AMPs remain as robust solutions. During AMP6 we have undertaken substantial groundwater investigations, under the NEP, to identify the key sources of nitrate and possible routes to their mitigation. We favour the catchment management approach to reducing inputs into the catchments, and these have been identified as primarily being agricultural in origin. This approach is consistent with the activities already being undertaken to manage the risks of metaldehyde. We are ensuring that the required catchment activity to manage these inputs is supported by the EA within WINEP-3.

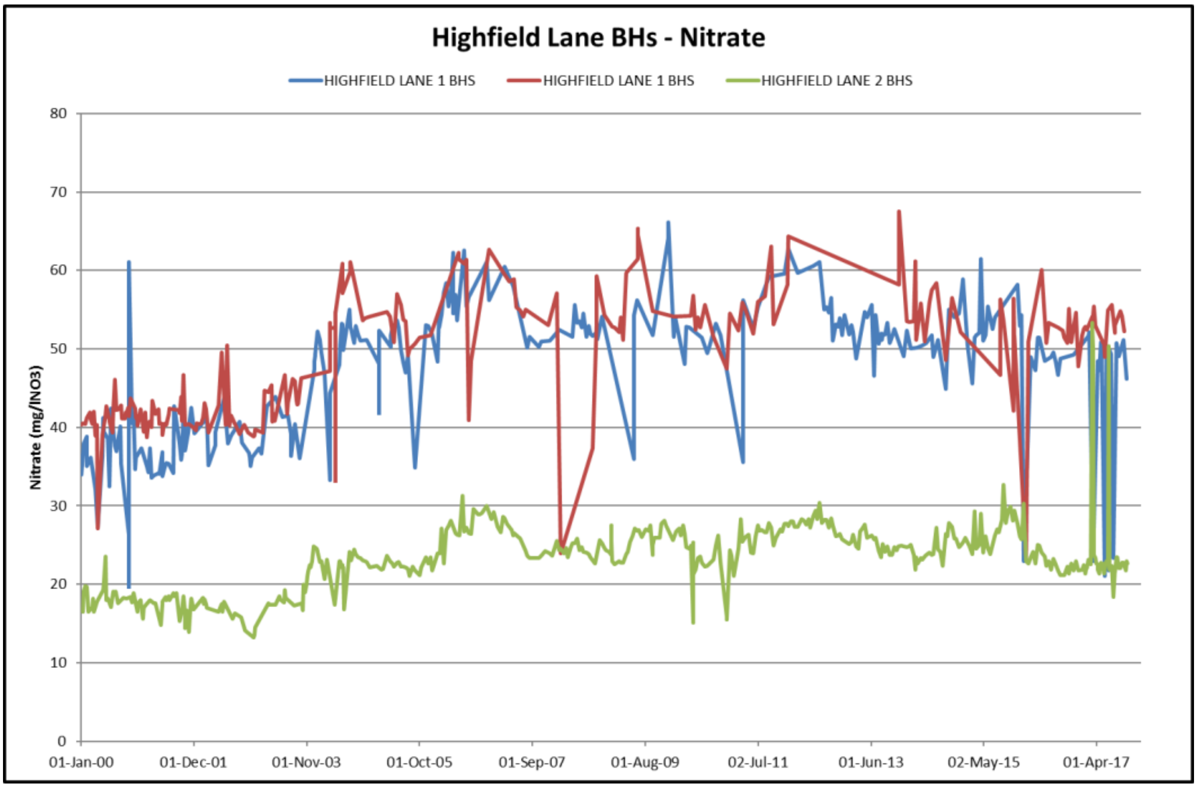

Figure. 3: Typical nitrate trends for Yorkshire groundwater sources.

1.3 Customer acceptability (non-discolouration related)

1.3.1 Earthy Tastes & Odours – algal derived

Within DWSPs, and having reviewed data from routine surveillance monitoring, water quality impacting events, and customer contact data, we have identified one site where a more resilient treatment solution is required to mitigate hazards which are increasing in severity and over time will result in more frequent risks to drinking water quality or customer acceptability.

The hazards identified are: -

- An increasing loading of algae from the river and raw water storage reservoirs leading to concentrations of MIB and geosmin which trigger customer contacts, both background and as part of water quality events.
- Algal by-product concentrations which are increasing beyond the removal capability of installed processes.

We have had limited success in the implementation of short-term mitigations such as the use of barley straw and dosing of powdered activated carbon (PAC). The latter has significant impact on the key treatment processes which are relied upon for the production of compliant water. We have considered and discounted a number oif other options:

- Shading of storage reservoirs, this is not feasible as located within a SSSI.
- Storage reservoirs mixing – the storage reservoir is too shallow for mixing to have an impact.
- Nutrient input reduction through catchment management is a long-term goal, but unlikely to address the risk in the required time-scale.

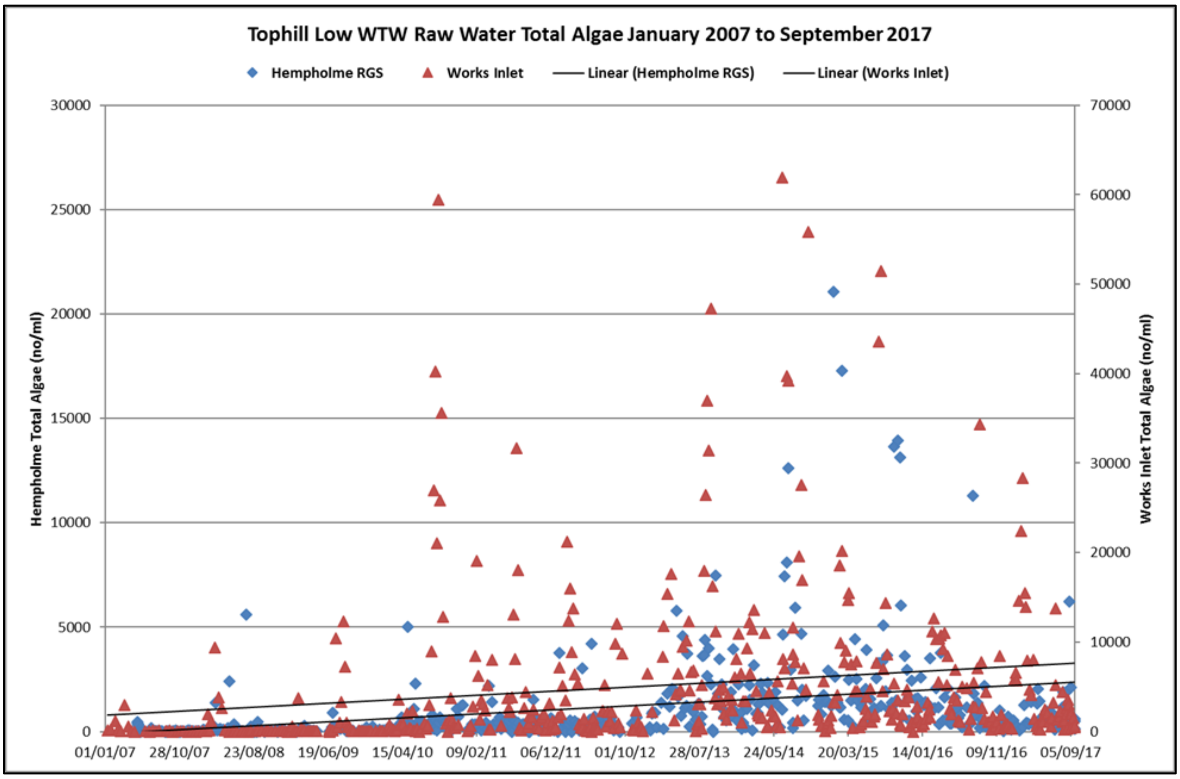

Figure. 4: Tophill Low WTW raw water algae trend.

For most of the sites impacted by algal related raw water deterioration we can see that PAC dosing will be sustainable in the medium term; however, for one site we believe that a long-term sustainable solution is required; this is discussed further in section 2.6.

1.4 *Cryptosporidium*

We have reviewed all raw waters for *Cryptosporidium* risk, and considered how well this is matched by the capability of the downstream processes to mitigate the risk effectively and in accordance with the Company's Disinfection Policy.

One site has been identified where the treatment capability and raw water risk mean enhancement to the treatment process is required.

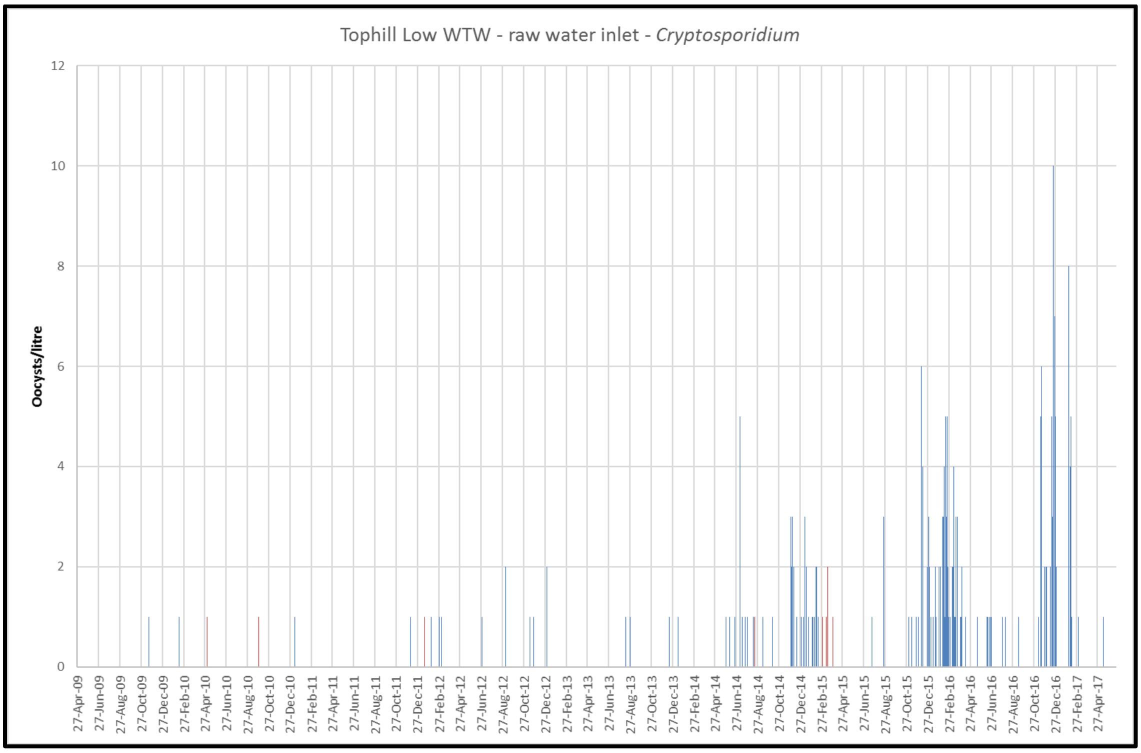

Figure. 5: Increasing trend in concentration of oocysts in raw water.

There is an increasing number and scale of detections of *Cryptosporidium* oocysts in both river water and raw water leaving storage. This has the potential to increase beyond the capacity of current treatment processes, suggesting intervention is required to meet our Disinfection Policy.

1.5 Metaldehyde

Metaldehyde remains a significant risk to compliance in the supplies abstracting water from the large lowland rivers of North and East Yorkshire. This is an area of circa 5,000km^2, much of which is in used for arable farming.
We do not propose making any proposals to DWI to install treatment at any sites within AMP7 to address metaldehyde. We have researched and costed two viable solutions for those sites which remain at risk. These are based on high rate PAC dosing or, as an alternative, the use of ultra-violet (UV)/peroxide based treatment. We do not believe that ozone based technologies are feasible due to the relatively high levels of bromide in the waters concerned.

We are developing proposals within WINEP to scale up the activities undertaken as investigations during AMP6 into new sub-catchments. We are applying more intensive approaches in these and the existing sub-catchments identified as high risk.
The key activities identified are:

- The continued employment of Catchment Sensitive Farming Officers through Natural England.
- The deployment of additional Catchment Sensitive Farming Officers resource by YW.
- Development of more granular risk mapping and GIS tools to maximise impact of Catchment Sensitive Farming Officers.
- The development predictive techniques for our Service Delivery Centre, to allow improved decision making relating to abstraction.
- Consideration of targeted PES schemes.
- Consideration of soil health advice to minimise the use of chemical control products in general and more specifically metaldehyde.
- Ways of driving best practice farming activities from the early adopters into the catchments.
- Working with the supply chain for arable products to promote metaldehyde free approaches.
- Developing an innovative system for the "loan" of equipment, which brings significant risk reduction into catchments as a means of driving the adoption of new slug control techniques into farming.
- More sustainable links with other catchment stakeholders such as the Rivers Trust and Yorkshire Wildlife Trust.

1.6 Other risks

1.6.1 Lead & Plumbosolvency control

Lead risk within the Yorkshire Region has been reduced over previous AMP periods and at present 99.6% of samples from an enhanced monitoring programme comply with the current standard at the customers' tap of 10μg/l Pb. This has primarily been achieved by phosphate dosing and pH management across all but tiny areas of the network, supported by lead pipe replacement where required.

1.6.1.a Plumbosolvency Control

We keep phosphate doses under review as are treated water pH levels, to ensure that the conditions for optimal plumbosolvency control are being achieved within the network. However, we recognise that Industry best practice in this regard is currently based on relatively old research and this needs to be refreshed. During late AMP5 we undertook scoping research with Huddersfield University to better understand the chemistry and solubility of the range of lead containing Apatite minerals which are the controlling factors for plumbosolvency, and which vary according to bulk water chemistry. This identified a number of potential areas of research toward better understanding the links between bulk water chemistry and potential lead concentrations, and the factors controlling the presence of particulate lead. This research is now underway, with a post-Doctoral researcher appointed, again at the University of Huddersfield, and is anticipated to conclude in 2019.

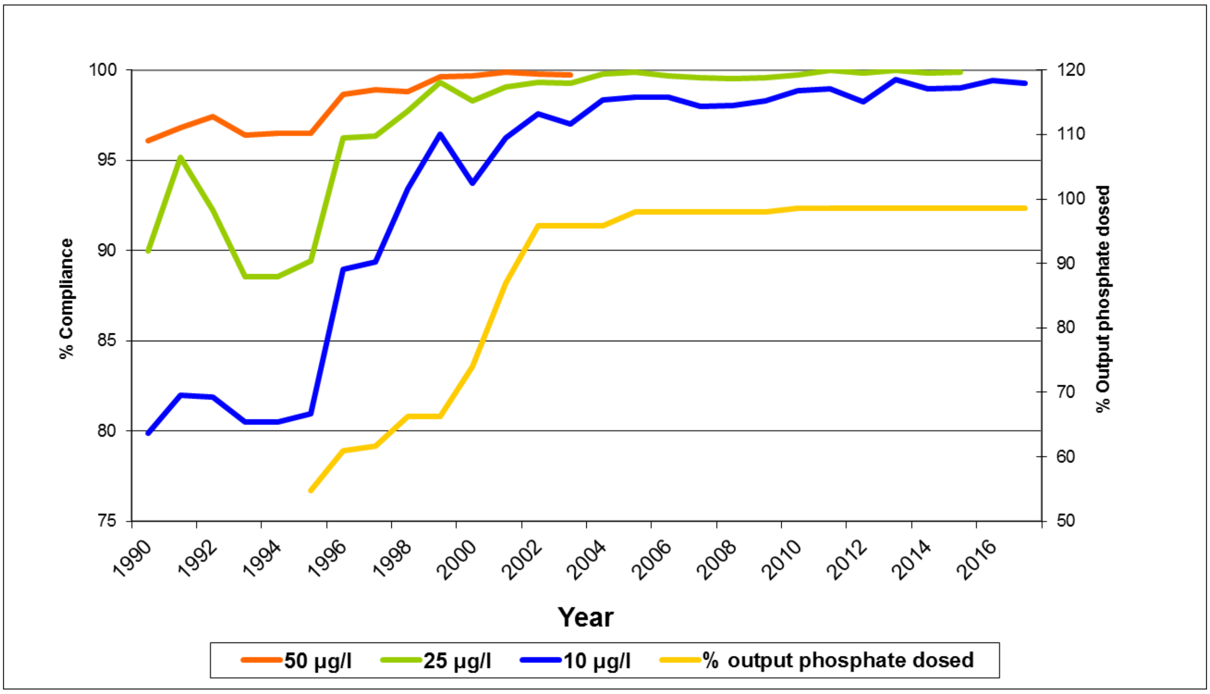

Figure. 6: Current management of lead risk.

1.6.1.b Lead pipe replacement

Communication pipes replacement or lining

For a number of AMPs this has formed the key approach to managing residual lead risk in those areas where plumbosolvency appears slightly less effective. We have good out-turn data from the AMP5 communication pipe programmes; in addition, we now have the out-turn data from a large-scale lead service pipe lining scheme within the current AMP.

AMP 5 – lead pipe replacement & lining

Although in the case of Water Supply Zone (WSZ) level replacement in AMP5, and DMA level replacement in AMP5 we were able to demonstrate benefits statistically, these benefits were relatively small. The table below compares the pre- & post- solution data from the WSZ level remediation programme in Leeds.

Table 3: Pre-and post-solution data from the WSZ level remediation programme in Leeds.

	Concentration - µg/l - total lead							
	Total no. of samples	Max value	Min value	Average value	No. samples >4	No. samples >7	No. samples >10	No. samples >25
WSZ level pre-data	399	128	<	2.75	75	40	23	3
WSZ level post-data	228	13.2	<	1.19	19	6	1	0

Some notable improvements have been observed when comparing the two sets of results;

- The pre-data shows that 23 samples were above the regulatory limit of 10µg/l (equating to 6%) – contrasting with only one sample being above that level in the post-data (=0.4%).
- When considering a lower threshold of 4µg/l, 75 samples were above that in the pre-data (=19%), whereas only 19 samples were above that in the post-data (=8%).
- Considerable improvements have also been observed in the maximum figures (128µg/l compared to 13.2µg/l) and of the average figures (2.75µg/l compared to 1.19µg/l) – the latter showing a substantial decrease of 57%.

The table below shows the respective pre- and post-monitoring summary results for the Hotspot DMA's remediation programme.

Table 4: Pre-and post-monitoring summary results for hotspot DMAs.

	Concentration - µg/l - total lead							
	Total no. of samples	Max value	Min value	Average value	No. samples >4	No. samples >7	No. samples >10	No. samples >25
WSZ level pre-data	59	29.2	<	4.97	28	20	8	1
WSZ level post-data	29	41.8	<	3.24	6	2	1	1

Although perhaps not as striking as those observed at the two WSZ's, there are still some improvements observed for the programme addressing Hotspot DMA's;

- The pre-data shows that 8 samples were above what is now the regulatory limit of 10µg/l (equating to 14%) – contrasting with only one sample being above that level in the post-data (=3%).
- When considering a lower threshold of 4µg/l, 28 samples were above that in the pre-data (=47%), whereas only 6 samples have been above that in the post-data (=21%).
- Improvement has also been observed in the average figures (pre = 4.97µg/l, compared to post = 3.24µg/l) - a considerable decrease of 35%.

AMP 6 lead service pipe lining trial

Our AMP6 large-scale pilot, in which the whole of the lead service was lined for around a thousand social housing properties in Rotherham Metropolitan District Council area, gave us the opportunity to understand both the logistics and potential benefits of this approach.

In total, 987 service pipes were lined and 16 service pipes were renewed. Where the property's pipes were renewed, it was because it was not technically feasible to carry out the lining. In total, 79% of the properties were council owned, and 21% were currently privately owned.

To assess the benefit of the lining programme in Rotherham (the work commenced in the summer of 2016 and concluded in early 2017), 95 households located in 16 streets were selected. We gathered data on their lead concentrations before and after the rehabilitation had taken place. The summary statistics for the data is displayed and described below:

Table 5: Pre and post lining sample summary results.

		Concentration - µg/l – total lead					
		Mean	Median	Min	Max	Range	Standard deviation
Original data	Pre-First Draw (1)	497.2	2.2	0.4	44200	44199.6	4534.7
	Pre-3 Min Flush (2)	14.9	1.1	0.2	1020	1019.8	105.1
	Post-First Draw (3)	1.7	0.9	0.1	35.4	35.3	3.8
	Post-3 Min Flush (4)	0.3	0.3	0.1	3	3	0.3
The difference	(1) - (3)	495.5	1.3	0.3	44164.6	44164.3	4530.9
	(2) - (4)	14.6	0.8	0.1	1017	1016.8	104.8
	(1) - (2)	482.3	1.1	0.2	43180	43179.8	4429.6
	(3) - (4)	1.4	0.6	0	32.4	32.3	3.5

It is perhaps easier to see this data graphically and the graph below shows a boxplot of the results. The median lines clearly show the differences between the four sets of data collected. As can be seen, the exposure to lead is reduced from simply carrying out a 3-minute flush at the tap – which is consistent with our advice to customers with lead pipe. However, from the results it is clear that there are lower concentrations of lead in the post-lining sample results and the highest quality of water was observed post-lining and after a 3-minute flush. These latter results also gave the lowest range of results. The results of post-sampling for the AMP 6 Hotspot communication pipe remediation programme are not yet available.

It is clear that the results of sampling confirm the intuitive position that the greater proportion of lead pipe that is remediated the greater improvement in water quality delivered, as this removes contact with lead from closer to the point of consumption (it is generally the last 8m of pipe which has the greatest influence on the compliance sample, and potentially the consumption of occupants).

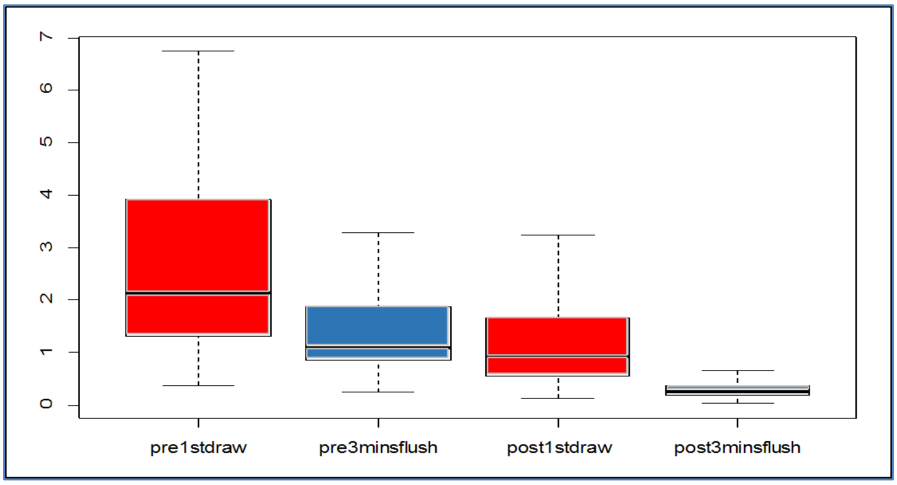

Figure. 7: Lead sampling results.

As this submission precedes the development of the long-term strategy for lead we believe that it is appropriate to pause widespread communication pipe lining or replacement, and to undertake more targeted activity during AMP7. In section 2.7 we further discuss our proposals for action during AMP7.

2.0 Part B – Site specific proposals

In this section, we identify the specific interventions for which we seek DWI's support. For each site, we have identified the optimal solution, and an alternative which has the potential to address some or all the risks. The workshop process to identify outline and cost the six treatment schemes included in part B of this submission has followed three main phases; risk identification; solution development & optimisation and costing (Figure 8). These involved the Company's technical experts, Process Engineering Consultants, and our Delivery partners. In this way, we have developed proposals for which we have a high degree of confidence in their deliverability.

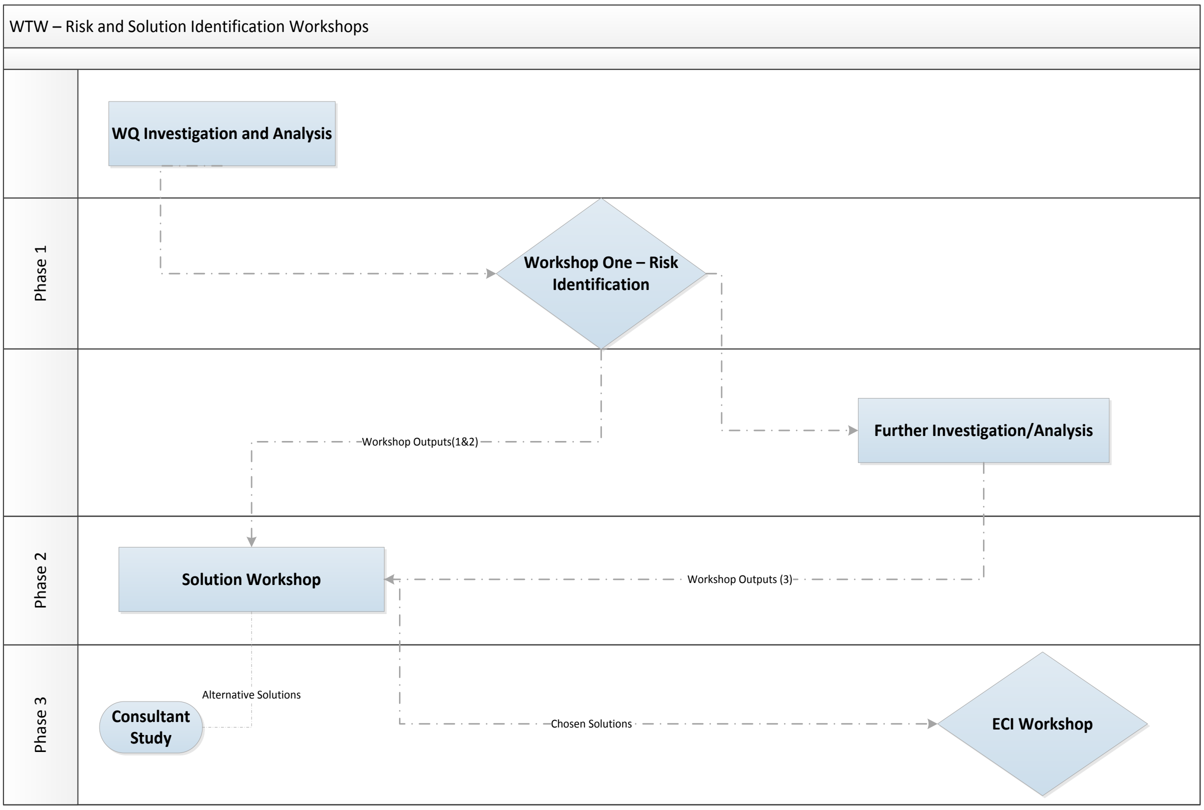

Figure. 8: Risk and solution identification workshop diagram.

Raw Water Quality, Treatment capability & DWSP Investigations and analysis

We began the process of identifying sites for detailed investigation by bringing together the specific expertise of raw water specialists, treatment specialists, DWSP Team, and members of our Asset Planning team. They systematically began with a review of all raw water sources, followed by treatment assessments. We brought the output from these reviews together with the in-depth site knowledge of Asset Planning engineers.

From the outputs of this process we derived a set of catchment management priorities to assess for inclusion in WINEP, together with a longer list of twenty WTW sites to investigate further.

Risk Identification Workshops

In these workshops, we reviewed twenty Water Treatment Works (WTW) across the Yorkshire region which had been prioritised on a risk based approach. The aim of the workshops was to complete a source to tap study; considering raw and treated water supply systems as well as the WTWs performance. All WTWs were ranked based on DWSP red risks, raw water quality colour trends, operational performance, flow adherence (MLD) and the compliance dashboard. The risk identification workshops were attended by representatives from Asset Strategy, Water Quality, Asset Planning, Asset Integrity and Service Delivery.

Data packages for each workshop were produced and contained the following items:

- Long-term raw water quality trends,
- Historic raw water quality data,
- Treated water quality data,
- Supply and demand requirements,
- WTW design envelopes,
- Asset condition survey outputs,
- Items included in Yorkshire Water's risk register, and
- Works information including schematics.

Founded on this data, risks were presented and categorised based on short-term operational risks, medium-term maintenance risks and long-term fitness for purpose risks. The risks outlined for the DWI submission were aligned with those identified for the WRMP, Base Maintenance planning, and the WINEP Programme (Figure 9).

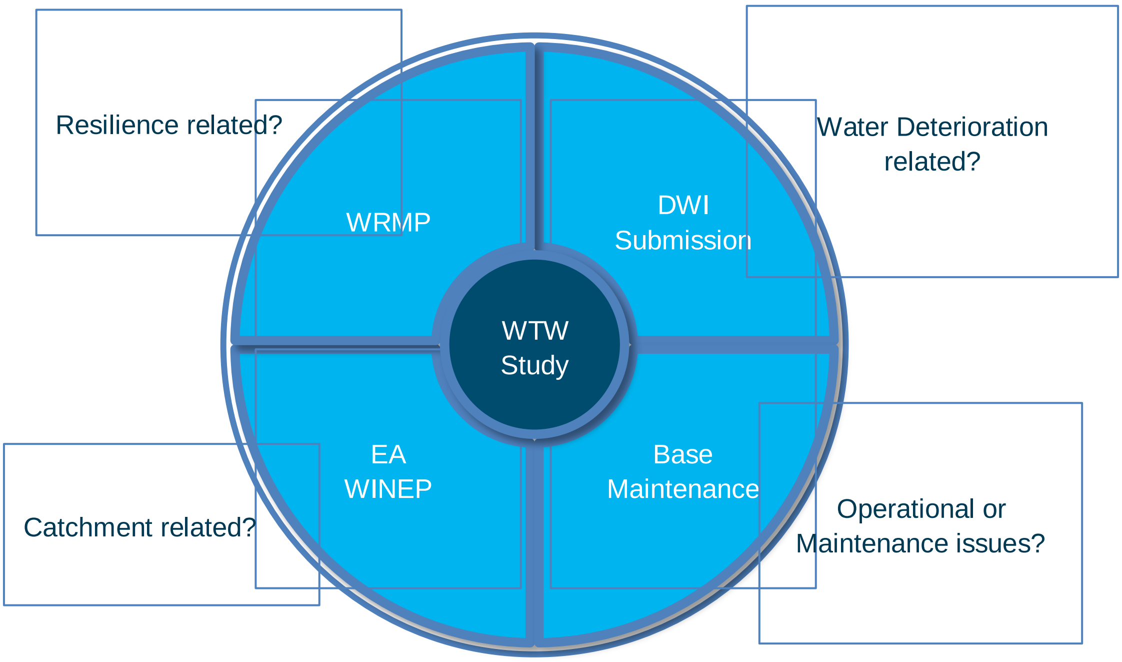

Figure. 9: WTW study diagram.

We recorded risks at the workshop and each was linked to a service impact on customers through the Service Measure Framework. Following a total of 20 sessions, the six sites included in this submission were prioritised for the solution development workshop.

The solution workshops developed primary and secondary solutions to be partially designed and costed at the ECI workshop. The focus was directed at developing the most efficient technical solution to fully resolve water quality, base maintenance and water supply resilience risks.

Early Contractor Involvement (ECI) Workshops

The ECI workshops further developed the solution to add the elements that have not been previously picked up in a high-level price review process. Sessions lasted three days which including a site walk-through and feasibility study. Attendees included a wide range of internal YW experts as well as several external contract partners. The costing workshop outputs was a list of elements to be costed by both the YW costing team and the contract partners who would potentially be delivering the scheme. A comparison and critique of the internal and external costs was completed to determine the final figure for inclusion in this document. This process has allowed us to develop costs for the proposed schemes that are both robust and resilient.

2.1 Chellow Heights WTW

2.1.1 Overview

Chellow is a highly strategic asset, with a current maximum output of 175Ml/d. It is the sole source of water to much of the City of Bradford, with only limited support from other systems. It is a large and complex site, with much of the infrastructure not designed for 21st century regulatory requirements. A significant number of assets are life-expired and pose risks to the reliability of supply in the event of failure. In addition, deterioration of the raw water quality in respect of organic colour, now risks compliance with standards or regulatory requirements. The proposed PR19 scheme addresses both new quality obligations, and resolves other risks to enable the quality investment to perform satisfactorily. In addition, the delivered scheme would incorporate significant base-maintenance investment to improve the overall resilience of the site, and aid recovery from failure.

Table 6: Scheme costs.

Site	Capex (£million)	Opex per annum (£million)
Chellow Heights WTW	£ 23.9	£ 1.1

Table 7: Alternative solution costs.

Site	Scheme	Technically Feasible	Risk Addressed	Lowest WLC
Chellow - Chosen	100Ml/d I-Ex / PAC refurb / chemical dosing / run to waste	Y	Y	N
Chellow - Alternative	GAC abs post RGF / Run to waste	Y – but space constraint	PART	Y
	WLC assessment includes all base maintenance investment required to deliver scheme.			

Table 8: Overview of DWSP Risks to be addressed.

Risk	Solution
DBP risk – Reg26 compliance / Public Health impact / compliance risk	Install ion exchange DOC removal stage on Nidd Aqueduct inlet (100Ml/d) – includes facility for expansion for full flow (207Ml/d) if other raw water sources deteriorate
Lack of run to waste/start to waste facilities	Installation of 2 new run to waste tanks (25Ml) and associated valves and control system
Turbidity risk – entering final stage of disinfection	Installation of run to waste system and improvements to resilience of key chemical dosing systems

2.1.2 Detail of risks to be resolved

Colour / Regulation 26 compliance (DBPs)

High colour levels in the catchment (upper Nidderdale - Scar House and Angram impounding reservoirs (IREs), and mid-Wharfedale - Barden IREs) expected to plateau in this AMP period but currently in occasional breach of DWI Reg26 guidance for DBPs. There has been a long-term increase in colour trend in the Nidd catchment from 1987. Statistical analysis suggests that this trend, although slow, is continuing and therefore the risks from DBPs are increasing as a consequence.

It is noted and predicted that maximum colour events are becoming more frequent as a result of changes to land use and weather patterns. There is also a gradual change in the nature of DOC chemistry and the balance between hydrophilic & hydrophobic fractions resulting in increased risk of DBP formation over time.

Table 9: Statistical analysis of colour trends.

	JAN 1998+							
	By MONTH				By YEAR			
Site	Max	Mean	Median	Min	Max	Mean	Median	Min
Chellow Heights Chelker	-0.321	-0.244	-0.244	-0.13	0.311	-0.176	-0.142	-0.1
Chellow Heights Nidd	-0.282	0.339	0.214	0.992	-0.833	-0.199	-0.121	1.83
	JAN 2004+							
	By MONTH				By YEAR			
Site	Max	Mean	Median	Min	Max	Mean	Median	Min
Chellow Heights Chelker	-0.12	0.096	0.179	0.39	-0.047	0.129	0.322	0.602
Chellow Heights Nidd	-1	-0.847	-0.938	-0.665	-1.414	-0.971	-0.841	1.684
KEY:	Highly sig (@1% level)	(@ 5% lev	Non sig					

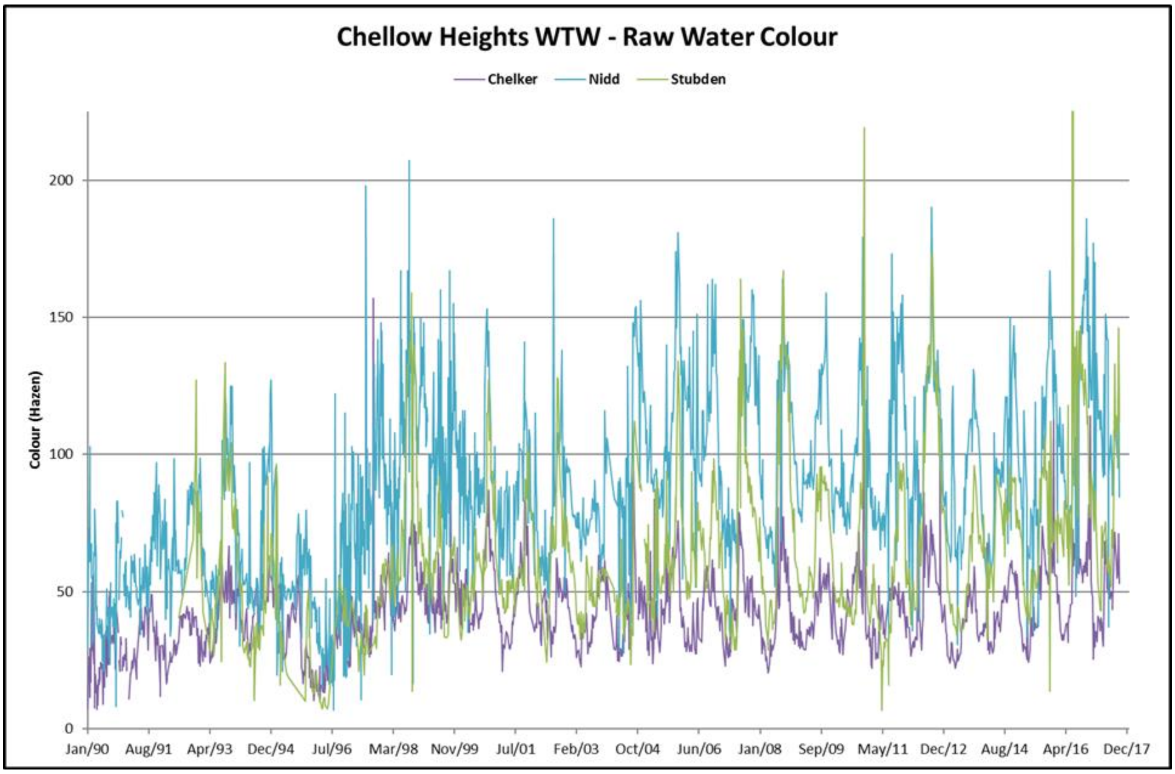

Figure. 10: Historical raw water colour trends at Chellow Heights WTW.

In addition, the site uses aluminium sulphate as coagulant which is less effective at the removal of DOC than ferric sulphate. Trials using ferric sulphate as coagulant were unsuccessful due to the higher alkalinity of the other raw water streams in the blend at Chellow WTW. This results in extremely high acid doses to pH correct the dosed-water to the optimal value for organics removal, along with producing very high sludge volumes.

Although catchment activity has been undertaken in the current and previous AMPs the raw water is still deteriorating, albeit relatively slowly in recent years. We will continue to invest in the catchments to ensure the sustainability of the solution proposed for the long-term.

2.1.3 Site Resilience - Regulation 26 Compliance (turbidity-preparation for disinfection)

Chellow WTW cannot be easily shut-down due to its raw water supply configuration, and currently has no turnout or run-to-waste facility. Failures in treatment therefore pose a risk to treated water quality and compromise compliance with the requirement to prepare water for disinfection (<1 NTU at point of entry to final disinfection stage). Bypasses on the inter-stage pumps to the manganese filters can allow rapid gravity filter (RGF) treated water into the contact tanks under certain unusual operational conditions. This can occur when flow through the preliminary processes exceeds 175 Ml/d or the inter-stage pumps fail; this is also a potential breach of Regulation 26.

The existing site is congested and complex, having been extended over the years, and with the added constraints of the land falling away on all sides of the site due to its hill top location, neighbouring premises, and existing process units.

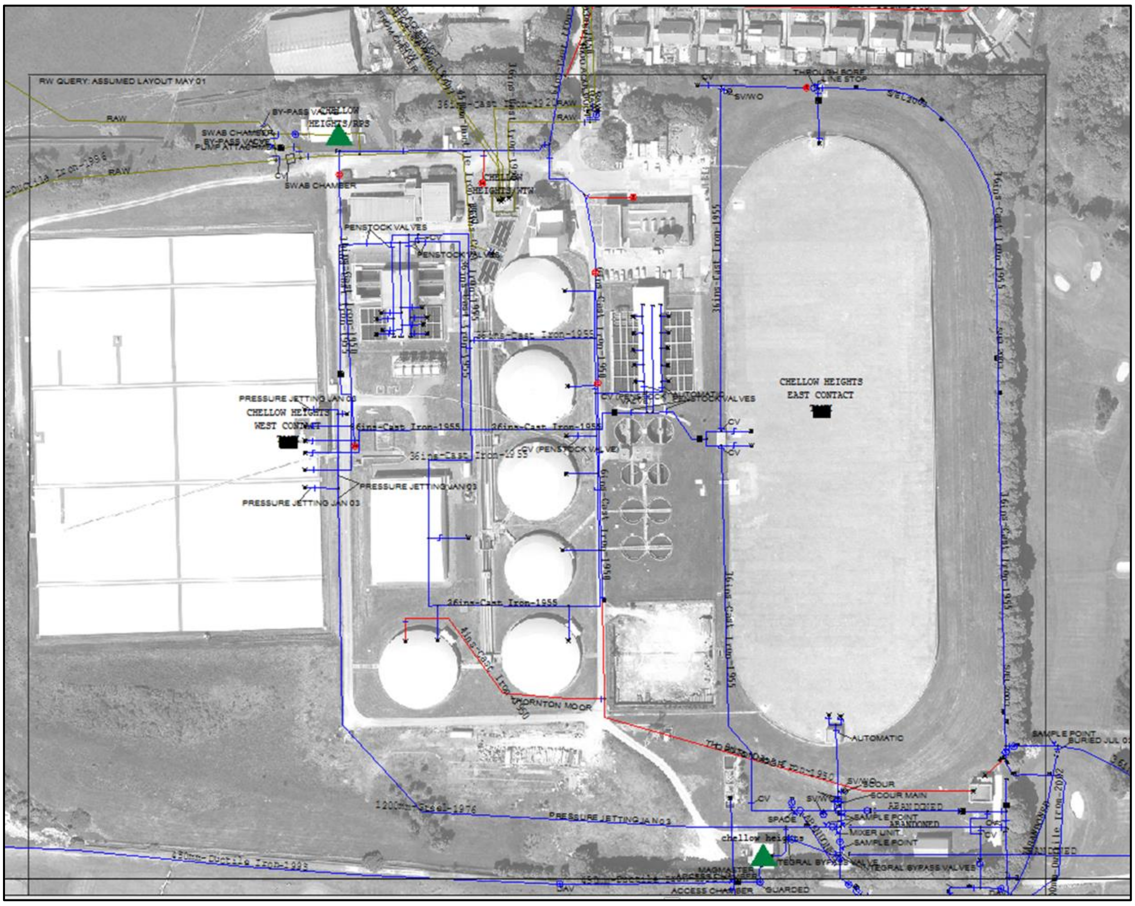

Figure. 11: Chellow WTW – site overview.

2.1.4 Proposed solutions

The solution proposed is targeted at resolution of the risks as described above. It includes the following key enhancements and additions to the existing processes.

Proposed solution - Colour/DBPs

The installation of an ion exchange process to reduce the colour/DOC loading on the coagulation process is the most logical approach to reducing DBP risk in treated water. At this stage, it is considered appropriate to provide this treatment for the highest risk raw water source only, but the installation will be planned so as to make provision for future expansion should raw water deterioration accelerate or catchment management prove less successful in managing the risk in the other sources.

The company experience is that, although the ion-exchange process typically removes around 30% of influent DOC, it reduces trihalomethane formation potential (THMFP) more significantly as it removes the DOC fractions which are not easily removed by coagulation. It therefore is highly effective in reducing DBP formation overall. Yorkshire water have been operating processes of this type for around 10 years at three sites, and are currently installing a fourth.

Most of the installation of this process is made above ground, in stainless steel or similar materials. This avoids the commitment in long asset life equipment which, were catchment management to be successful over time, would become redundant. Thus, although treatment investment is now considered unavoidable, the process units could be removed and recycled effectively or deployed elsewhere.

Proposed solution – Site Run/Start to Waste

The proposed solution has to fulfill two key requirements:-

- The ability to divert the full Nidd aqueduct flow to waste in the event of a total site power failure; this to allow time to safely reduce flows entering the site by opening key vales on the upstream raw water system. Initially this could be of the order of 100Ml/d reducing quickly to lower values.
- The ability to run the process to waste on start-up, or following the failure of key processes, and thus prevent inadequately treated water from entering the final stage of disinfection or being supplied to customers. Initially this could be of the order of 175Ml/d, again reducing quickly to lower values.

It is proposed to construct two run to waste tanks with a total volume of 25Ml.

The proposed locations for additional or re-located process units are shown on figure 12 below:

- An ion-exchange process, designed for DOC removal (for example, MIEX) to treat the full flow to site from the Nidd aqueduct (~100Ml/d). This will be located where the existing control room building stands. This location is critical as all the Nidd aqueduct raw water mains enter the site in the north central area.
- A new control room will be constructed adjacent to the old "Alum House".
- The sulphuric acid and PAC dosing systems currently in the basement and alongside the existing control room building will be relocated to the north edge of the site in separate buildings.
- A new motor control centre (MCC) building will also be constructed to the west of the existing building to replicate the existing MCC units for the "west" electrical supplies.

- The polyelectrolyte system in the existing building will be re-created in two separate units: one to house and dose polyelectrolyte for the clarifiers (and an option to also dose the lamellas) which will be located to the west of the lamella units; and a second to dose polyelectrolyte to the sludge clarifiers on the east of the site.
- A new access road will be installed to this second polyelectrolyte unit.
- The hypochlorite storage tanks will also be relocated with a new dosing kiosk, approximately south-west of the lamellas.
- The lime system will be replaced as it is life-expired. (A temporary caustic soda dosing unit will be required during the replacement activity).

A Run to Waste (RTW) system will also be installed. This will consist of 2 concrete tanks (1 of 10 Ml, and 1 of 15 Ml) to be located at the southern end of the plant, in and around the old slow sand filter area.

Finally, the inter-stage pumps (RGF to Manganese Contactor) will be increased in size to allow 207 Ml/d throughput to the manganese contactors.

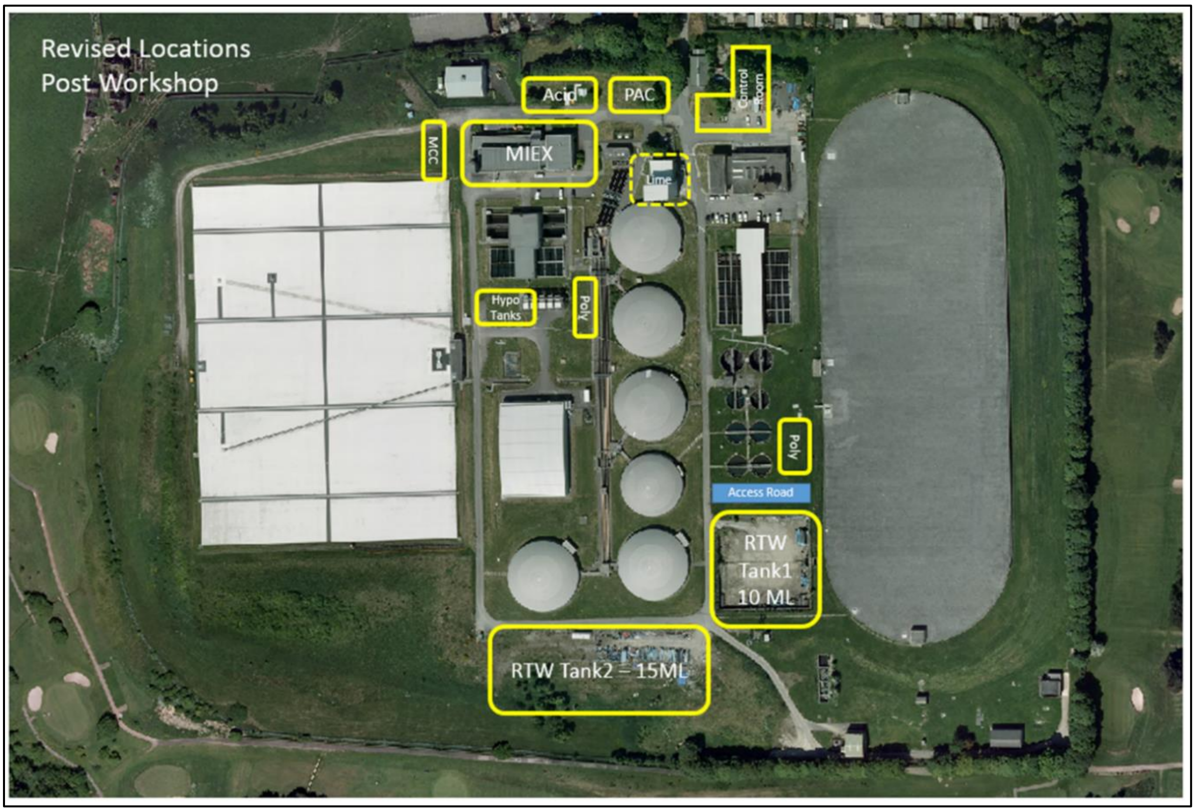

Figure. 12: Proposed location of new or relocated process units – solid lines / replaced process units – dotted line.

The process diagram below demonstrates the relative ease of integration of the proposed solution into the existing process and site.

By intercepting the raw water mains at the inlet, it is likely that there is sufficient head available to drive the raw water into the ion-exchange facility; from there the partially treated water follows the existing hydraulic pathway through the subsequent processes and on into the treated water tanks.

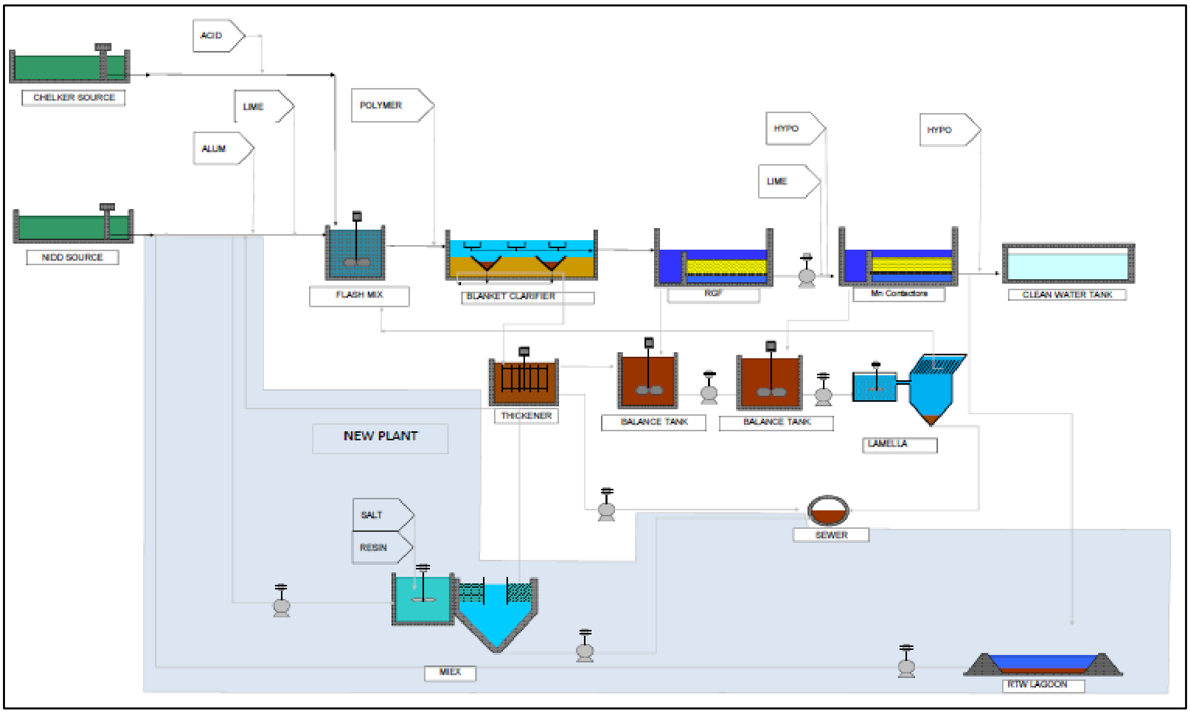

Figure. 13: Proposed new process schematic.

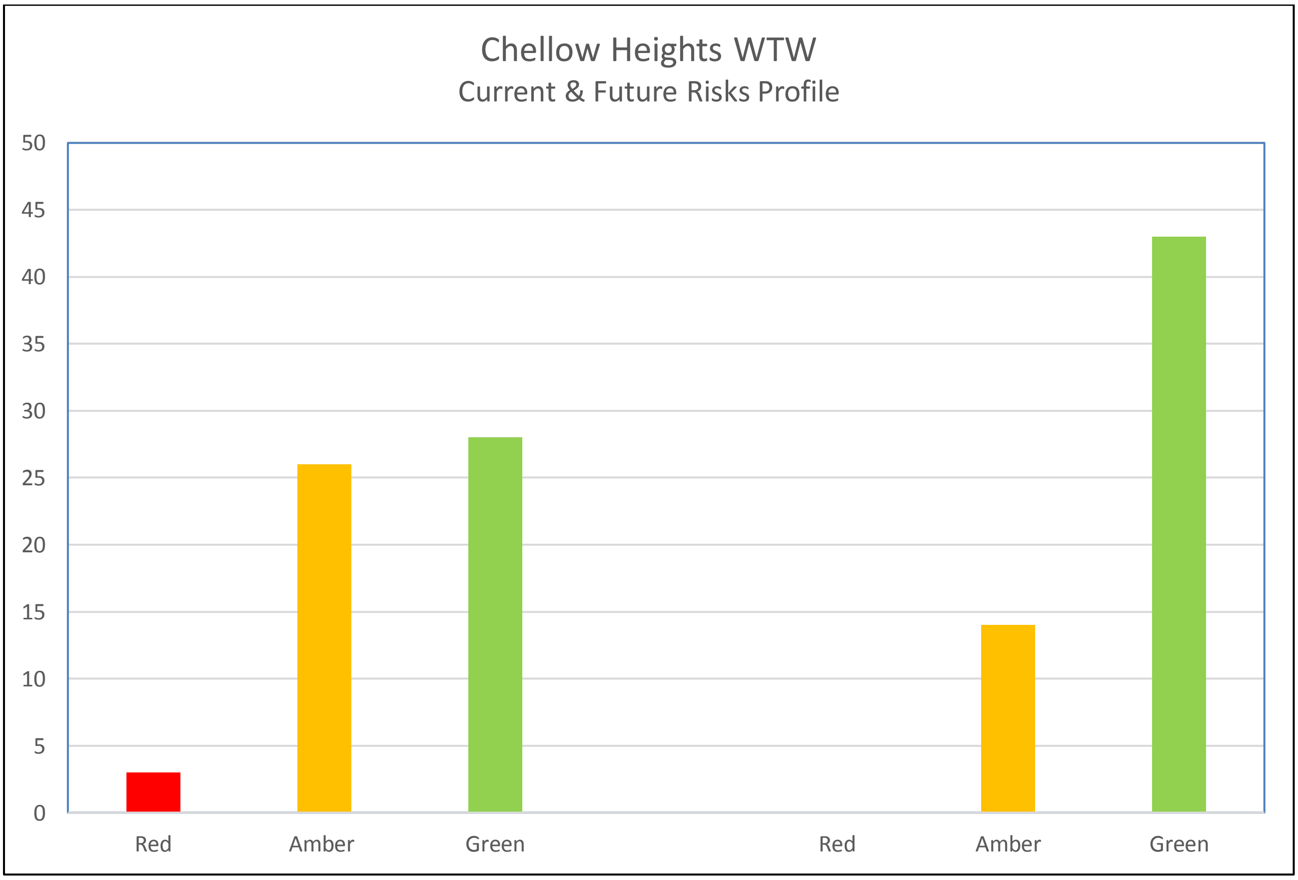

Figure. 14: DWSP change in risk position.

2.1.5 Other risks to be resolved:

- Pesticides - low-medium risk of pesticides in Chelker (River Wharfe) and Stubden sources.
  - Solution: - Existing PAC plant is to be replaced, alongside catchment management activity.
- Polyelectrolyte - Preparation and Dosing - The polyelectrolyte preparation plant is old and its control system unsupported. There are only 8 dosing pumps for 6 clarifiers (1 standby per set of 3).
  - Solution: - Dedicated duty/standby dosing to be provided (Q-related base)
- Sulphuric Acid - The sulphuric acid plant is in a basement. The tanks and bund are life expired and inadequate. Ventilation is poor and there are considerable associated Health and Safety (H&S) risks.
  - Solution: - replacement storage & dosing systems (Q-related base / H&S Driver)
- Control Room Building - The control room building is >70 years old and in poor structural condition. The sulphuric acid, polyelectrolyte, PAC and bulk hypochlorite storage facilities are all within / under this building. In order to build the MIEX plant at the optimum location to intercept multiple large raw water mains, the current Control Room / Chemical House building will need to be relocated.
  - Solution: - new Control Room building / Chemical House building(s) (base)
- Maximum Treatment Capacity - The WTW is limited to 175 Ml/d. Flows greater than 175 Ml/d would be diverted on a bypass main around the manganese contactors; this has also occurred due to power failures impacting the inter-stage pumps.
  - Solution: - new flow control system / run-to-waste facility (base)
- Lime preparation system required – Replacement due to life expired asset
  - Solution: - New system to be provided (base)

2.1.6 Alternative solutions considered

As part of the workshop approach to identifying the most appropriate solution a number of alternative solutions or partial solutions were identified. These provided less certainty around resolving the risks either individually or in combination, and were therefore rejected.

The potential alternatives are as follows and include options reviewed in pre-workshops and from this review.

Table 10: Alternative solutions.

	Description	Advantages	Disadvantages	Progress

1	New PAC (Powdered activated carbon) storage and dosing plant (existing non-functional)	Low capital cost	High opex cost Capacity is limited to maximum dose that can be applied due to carry through to RGF, (heavy blanket, increases in coagulant demand). Inefficient as applied at front end.	No
2	GAC (Carbo plus)	Operational flexibility. Will also tackle pesticides 12 months of the year. (pesticide CM investigation ongoing) More cost efficient than PAC. Does not increase load onto clarifiers as with PAC.	New technology – untested in UK. (is used in Europe). May increase solids load on Manganese Contactors from carryover. Not flexible for flow variation.	No
2a	GAC (conventional without Ozone)	Operational flexibility. Will also tackle pesticides (pesticide CM investigation ongoing). More cost efficient than PAC. Does not increase load onto clarifiers as with PAC.	Bed life short (12 months), Use of Ozone to increase bed life and improve removal.	Yes
3	Change of coagulant to Ferric.	Effective for up to 200°H colour. Used successfully at most upland WTWs.	Chelker water high alkalinity, high acid doses required to achieve sufficiently low coagulation pH. Increased sludge production. Increased concrete corrosion risk with low pH (high carbonic acid).	No

			Blanket control may be more difficult (heavier blankets)	
4	Split Raw water sources and treat separately (different coagulants)	Does not need high levels of pH correction as per 3.	Complex to operate effectively two works	No

As Chellow WTW has manganese contactors which use chlorine to oxidise manganese from the raw water, the location of the GAC must be upstream of the manganese contactors so as to remove DBP precursors before chlorine is applied.

It is not possible to use ozone injection upstream of the GAC, as this would oxidise the manganese causing it to precipitate on the GAC, which is undesirable as it compromises regeneration. Therefore, the alternative option utilises GAC alone to remove dissolved organic carbon located following the rapid gravity filters and prior to chlorine dosing for manganese removal.

Filtered water from East and West RG Filters is intercepted in a valve chamber and flows under gravity to a pumping station. Here it is lifted to 22 number GAC absorbers through which water passes before being returned to the existing inter-stage pumping station.

The GAC are backwashed with low manganese water sourced from the manganese contactor outlet. GAC dirty washwater is returned to the manganese dirty washwater gravity transfer pipework. An additional DWW (Dirty washwater) Lamella is provided and existing lamella feed pumps uprated and polymer dosing added to handle the additional washwater.

The GAC system is designed for 9 months minimum operation between regenerations at maximum flow and at average flows every 13 months. Due to the short life of GAC when used for the removal of colour (Embsay trials – 18500BV) the GAC absorbers are large and have an empty bed contact time of 19 minutes.

In addition to the above the following would also be required as provided alongside the proposed solution:

- Run to waste Lagoon
- Lime plant upgrade
- New acid Plant

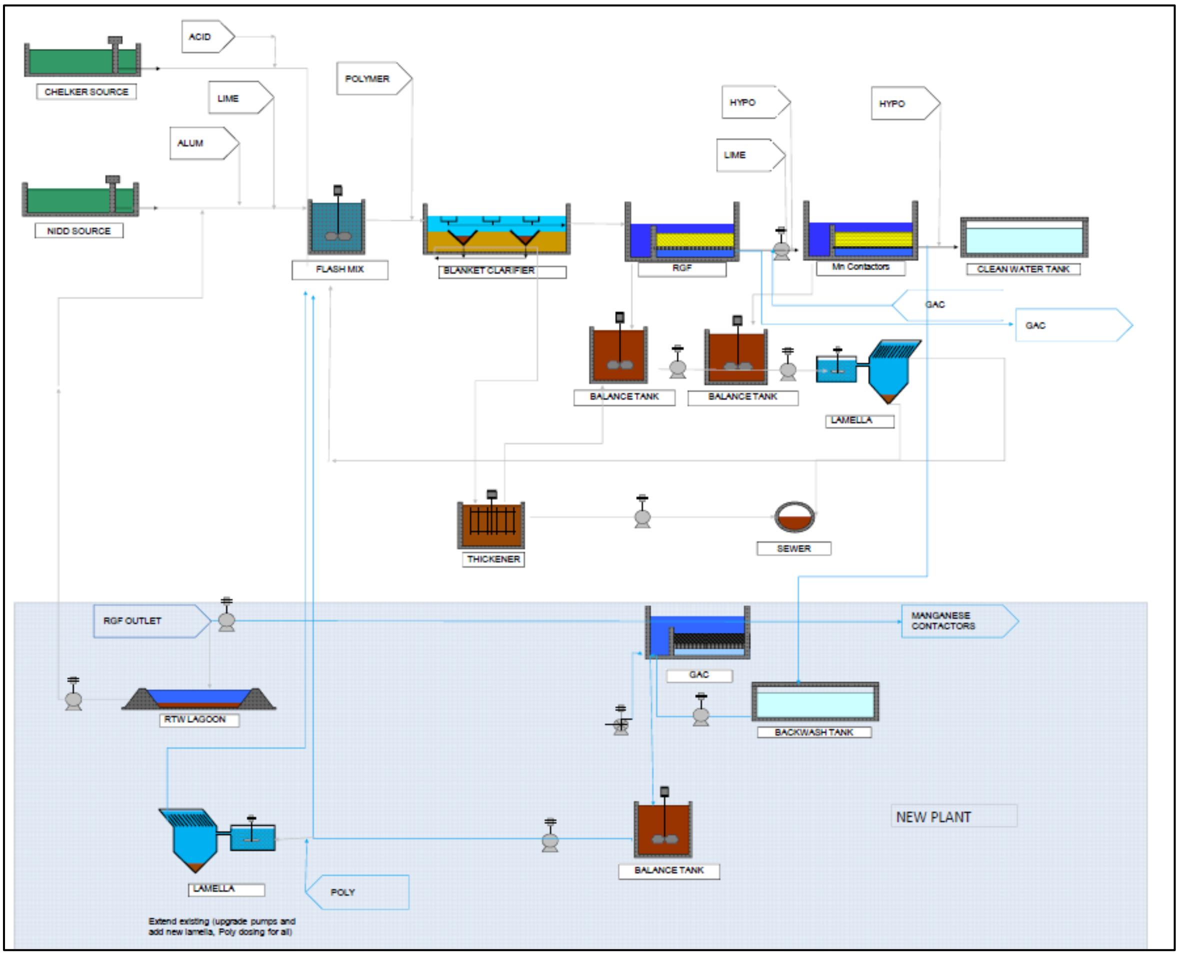

Figure. 15: Proposed solution process schematic.

2.1.7 Catchment Solutions

Alongside delivery of the proposed engineered solution we are proposing additional catchment measures to build on activity undertaken in the current and prior AMP periods. This will focus, as described previously, on the development of a health community of bog plants which protect the peat from drying and oxygen. We believe that this activity is key to ensuring that the engineered WTW enhancements remain sustainable for the long-term, and hold out the prospect of being able to reduce the intensity of treatment over time, for example by reducing the volume of water which has to pass through the ion-exchange process.

The Company is working with the EA in shaping the sites for inclusion in WINEP – the current list of sites associated with the raw water supplies to Chellow WTW are shown in the table below.

Table 11: Catchments submitted to WINEP.

Driver Description	WINEPID	Function	RBD	Area	Water Company	Unique ID	Scheme Name	Waterbody	Waterbody ID	Water Body Type(s)	WFD Catchment	Driver Code
Drinking Water Protected Areas	YOR00162	WQ	Humber	Yorkshire	Yorkshire Water Service Ltd	7YW200106	Scar House and Angram	Nidd from Source to Howstean Beck	GB104027068380	River	Nidd Upper	DrWPA_ND
Drinking Water Protected Areas	YOR00163	WQ	Humber	Yorkshire	Yorkshire Water Service Ltd	7YW200107	Angram	Nidd from Source to Howstean Beck	GB104027068380	River	Nidd Upper	DrWPA_ND
Drinking Water Protected Areas	YOR00164	WQ	Humber	Yorkshire	Yorkshire Water Service Ltd	7YW200108	Grimwith	Barben Beck/River Dibb Catchment (trib of Wharfe)	GB104027064120	River	Wharfe Upper	DrWPA_ND
Drinking Water Protected Areas	YOR00165	WQ	Humber	Yorkshire	Yorkshire Water Service Ltd	7YW200109	Barden Upper	Barden Beck Catchment (trib of Wharfe)	GB104027064060	River	Wharfe Middle and Washburn	DrWPA_ND
Drinking Water Protected Areas	YOR00166	WQ	Humber	Yorkshire	Yorkshire Water Service Ltd	7YW200110	How Stean	Howstean Beck from Source to River Nidd	GB104027068300	River	Nidd Upper	DrWPA_ND
Drinking Water Protected Areas	YOR00167	WQ	Humber	Yorkshire	Yorkshire Water Service Ltd	7YW200111	Ramsgill direct intake	Nidd from Howstean Beck to Ashfoldside Beck	GB104027068294	River	Nidd Upper	DrWPA_ND
Drinking Water Protected Areas	YOR00168	WQ	Humber	Yorkshire	Yorkshire Water Service Ltd	7YW200112	Upper Wharfedale Chelker	Wharfe from Oughtershaw Beck to Park Gill Beck	GB104027069290	River	Wharfe Upper	DrWPA_ND
Drinking Water Protected Areas	YOR00169	WQ	Humber	Yorkshire	Yorkshire Water Service Ltd	7YW200113	Stubden	Bridgehouse Beck from Source to River Worth	GB104027064200	River	Aire Middle	DrWPA_INV
Drinking Water Protected Areas	YOR00170	WQ	Humber	Yorkshire	Yorkshire Water Service Ltd	7YW200114	Thornton Moor	Bridgehouse Beck from Source to River Worth	GB104027064200	River	Aire Middle	DrWPA_ND
Drinking Water Protected Areas	YOR00171	WQ	Humber	Yorkshire	Yorkshire Water Service Ltd	7YW200115	Nidd intakes (direct)	Nidd from Howstean Beck to Ashfoldside Beck	GB104027068294	River	Nidd Upper	DrWPA_ND

2.2 Oldfield WTW

3.2.1 Overview

Oldfield WTW is an aging asset, with a current maximum output of around 12Ml/d. It is one of the supplies to the Keighley area to the west of Bradford, with only limited support from other systems. It is a complex site, with much of the infrastructure not designed for 21st century regulatory requirements. A significant number of assets are life-expired and pose risks to the reliability of supply in the event of failure. In addition, deterioration of the raw water quality in respect of organic colour now risks compliance with standards or regulatory requirements. The proposed PR19 scheme addresses both new quality obligations, and resolves other risks to enable the quality investment to perform satisfactorily. In addition, the scheme also incorporates significant base-maintenance investment to improve the overall resilience of the site, and aid recovery from failure.

Table 12: Scheme costs.

Site	Capex (£million)	Opex per annum (£million)
Oldfield WTW	£ 6.1	£ 0.1

Table 13: Alternative solution costs

Site	Scheme	Technically Feasible	Risk Addressed	Lowest WLC
Oldfield - Chosen option	DOC I-Ex / 3 stage rebuild / enhanced Run to Waste	Y	Y	N
Oldfield - Alternative	See combined solution	Y	PART	Y
	WLC assessment includes all base maintenance investment required to deliver scheme.			

Table 14: Overview of DWSP Risks to be addressed.

Risk	Solution
DBP risk – Reg26 compliance / Public Health impact / compliance risk	Install ion exchange DOC removal stage on raw water inlet (12Ml/d)
Aging Assets	Installation of 2 new run to waste tanks (25Ml) and associated valves and control system
Turbidity risk – entering final stage of disinfection	Installation of run to waste system and improvements to resilience of key chemical dosing systems

1. Long term increase in colour trend in the catchment: **Oldfield - Drinking Water Quality (Biological & Chemical).**
2. Max colour events more frequent: **Oldfield - Drinking Water Quality (Biological & Chemical)**
3. Change in nature of DOC changing chemistry (hydrophilic/phobic): **Oldfield - Drinking Water Quality (Biological & Chemical).**
4. Burst History of raw water main from Watersheddles IRE to WTW: **Oldfield - Water Supply Availability.**
5. Oldfield ageing plant - civils failures likely within 5-10 years - **Oldfield - Water Supply Availability.**

3.2.2 Detail of risks to be resolved

Colour / Regulation 26 compliance (DBPs)

High colour levels in the catchment (Watersheddles and Keighley Moor IREs, with occasional support from Ponden IRE). There has been a long-term increase in colour trend in these catchments and they have been subject to catchment management. Statistical analysis suggests that this trend, although slow, is continuing and therefore the risks from DBPs are increasing as a consequence.

It is noted and predicted that maximum colour events are becoming more frequent as a result of changes to land use and weather patterns. There is also a gradual change in the nature of DOC chemistry and the balance between hydrophilic & hydrophobic fractions resulting in increased risk of DBP formation over time.

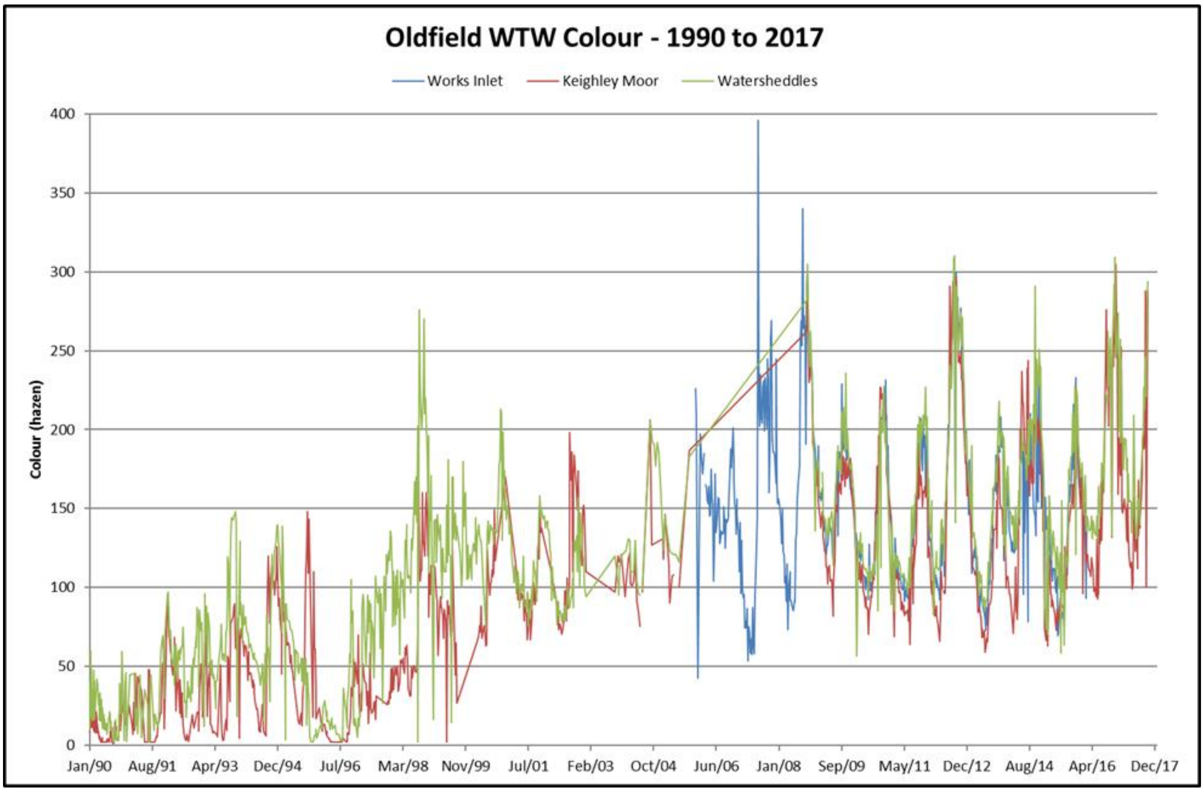

Figure. 16: Raw water colour trend at Oldfield WTW.

Table 15: Statistical analysis for colour trends at Oldfield WTW.

	1987 - 2015 Leeds	1998 to 2015 Leeds	1987 - 2015 Leeds			1998 to 2015 Leeds		
	By Month	By Month	By Year			By Year		
Site	Median	Median	Max	Mean	Min	Max	Mean	Min
Oldfield - KM	4.94	1.44	7.24	5.59	1.63	3.929	3.41	3.41
Oldfield - WS	4.72	0.99	6.63	5.1	3.51	4.039	1.73	3.06

KEY:	Highly sig (@1% level)	Sig (@ 5% level)	Non sig

Although catchment activity has been undertaken in the current and previous AMPs the raw water is still deteriorating, albeit relatively slowly in recent years. We will continue to invest in the catchments to ensure the sustainablility of the solution proposed for the long-term. Both catchments are included in the current version of WINEP from the EA.

Table 16: THM results in Keighley WSZ.

WSZ	Year	Average
	2010	48.78
	2011	47.34
	2012	50.03
	2013	41.87
	2014	44.80
	2015	47.74
KEIGHLEY 2004 WSZ	2016	51.42

3.2.3 Site Resilience - Regulation 26 Compliance (turbidity-preparation for disinfection)

Oldfield WTW has a number of engineering challenges which require resolution to assure the sites resilience and resistance to failure. Within the supply system there is limited water storage which limits the ability to shut the site down whilst maintaining supplies. Additional run to waste capacity is required to aid recovery from site shutdowns and protect treated water quality.

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3.2.4 Proposed solutions

The solutions proposed are targeted at resolution of the risks as described above. It includes the following key enhancements and additions to the existing processes.

Proposed solution - Colour/DBPs

The installation of an ion exchange process to reduce the colour/DOC loading on the coagulation process is the most logical approach to reducing DBP risk in treated water.

The company experience is that, although the ion-exchange process typically removes around 30% of influent DOC, it reduces THM Formation Potential more significantly as it removes the DOC fractions which are not easily removed by coagulation. It therefore is highly effective in reducing DBP formation overall. We have been operating processes of this type for around ten years at three sites, and are currently installing a fourth.

Most of the installation of this process is made above ground, in stainless steel or similar materials. This avoids the commitment in long asset life equipment which, were catchment management to be successful over time, would become redundant. Thus, although treatment investment in now considered unavoidable, the process units could be removed and recycled effectively or deployed elsewhere.

The proposed locations for additional or re-located process units are shown on figure 17 below:

- An ion-exchange process, designed for DOC removal (eg MIEX) to treat the full flow to site from the raw water sources (~12Ml/d). This will be located adjacent to the existing WTW.

Figure. 17: Proposed location of new or relocated process units.

The process diagram below demonstrates the relative ease of integration of the proposed solution into the existing process and site.

By intercepting the raw water mains at the inlet, it is likely that there is sufficient head available to drive the raw water into the ion-exchange facility; from there the partially treated water will move into the rebuilt section of the site. Much of the new WTW will be built adjacent to the current site which will ease the maintenance of supplies during construction.

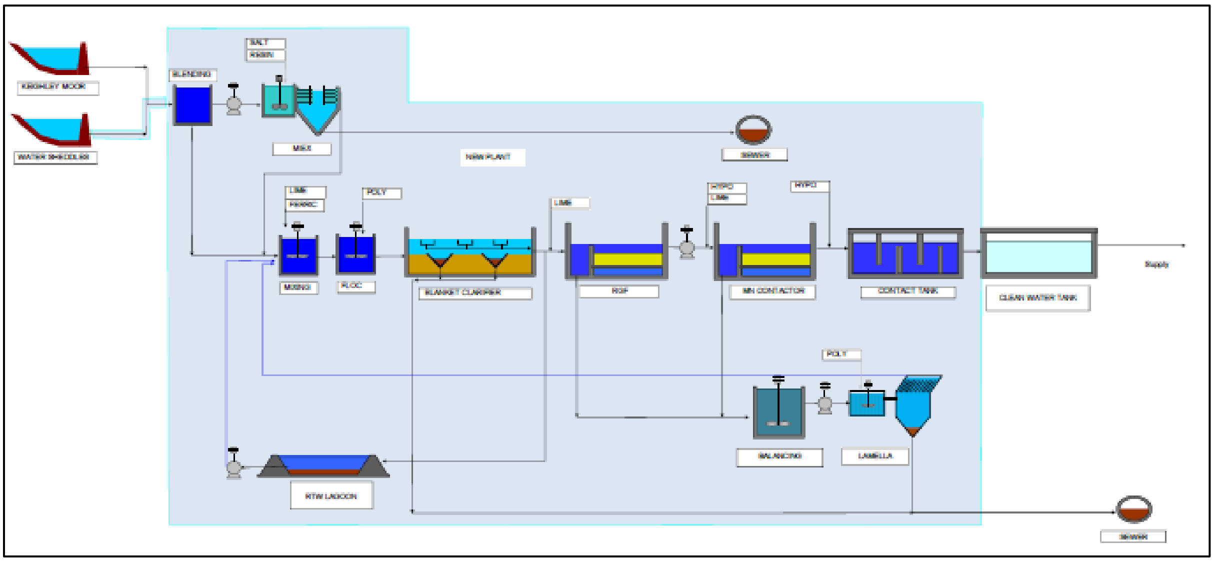

Figure. 18: Proposed solution process schematic.

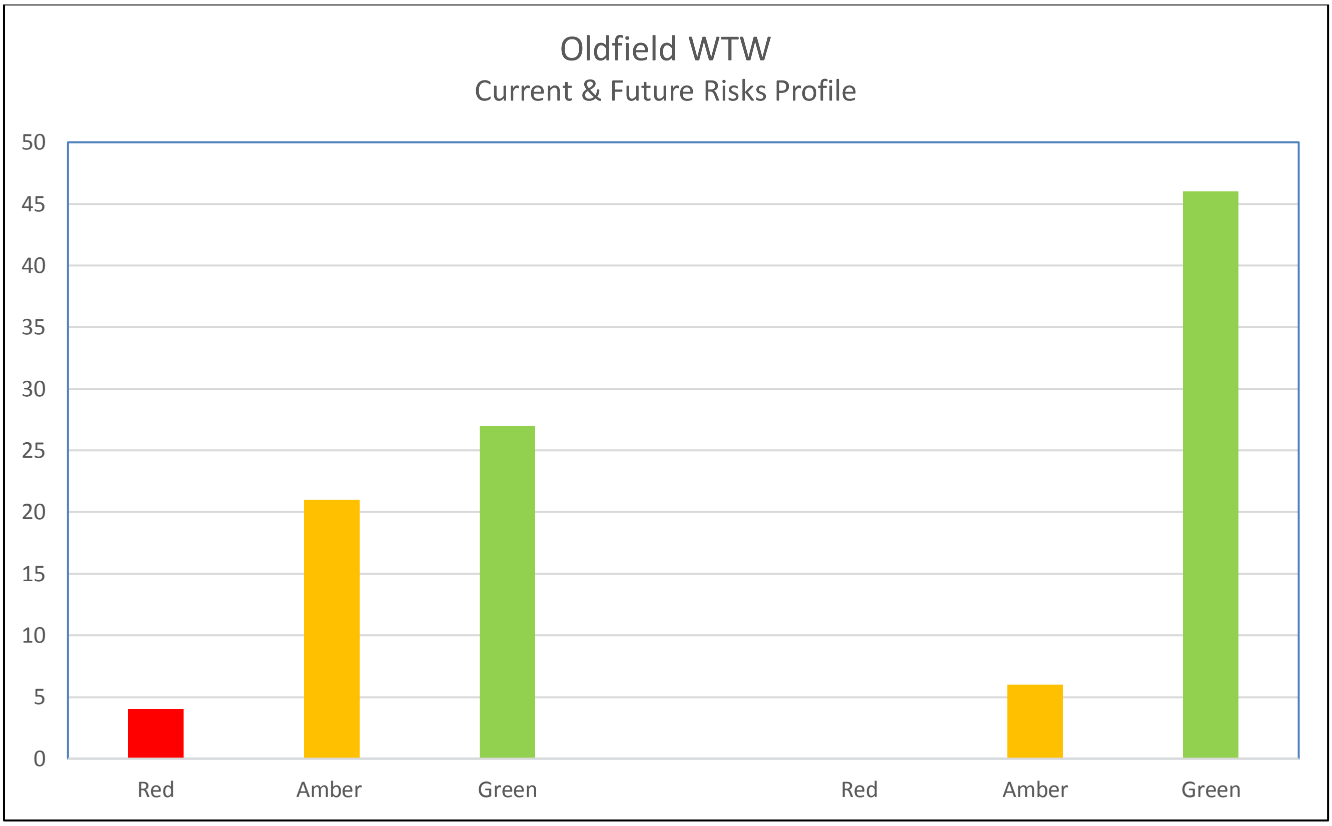

Figure. 19: DWSP change in risk position.

3.2.5 Other risks to be resolved:

Solution Overview:

1. Rebuild Oldfield WTW to 12 Ml/d capacity (at outlet) and provide MIEX plant of same size following completion and commissioning of new WTW and demolition of old WTW. Includes new contact tank (CT) and relocate run to waste tank (RTW) tank as per diagram.
2. Provision of 12 Ml/d MIEX at Sladen Valley.

Details - Oldfield

1. 12 Ml/d WTW (clarifiers / RGF / Mn / sludge thickeners) - as per Amey design proposals.
2. 1500 m^3 RTW utilising exiting 3rd SSF - as per Amey design proposals See no.8.
3. Demolition of entire old WTW at Oldfield.
4. Installation of new 12 Ml/d MIEX on site of existing Mn and washwater buildings (approx. footprint of 600m2 - 20m x 30m).
5. MIEX interstage PS.
6. Replacement of Watersheddles main (4,100m: 400mm)
7. Refurbishment / replacement of Ponden RWPS.
8. New CT approx. $1300m^3$.
9. New RTW and associated return PS. approx. $1250m^3$.

3.2.6 Alternative solutions considered

As part of the workshop approach to identifying the most appropriate solution a number of alternative solutions or partial solutions were identified. These provided less certainty around resolving the risks either individually or in combination, and were therefore rejected.

The potential alternatives are as follows and include options reviewed in pre-workshops and from this review. Arup conducted a feasibility study into the Keighley/Bradford Water supply system (WTW and Network Optimisation study). The study included review of Sladen and Oldfield and also the wider network and provided options and recommendations for individual works upgrades and combining of the WTW sites. The outputs of these studies and recommendations have been reviewed to determine potential alternatives to the main proposed solution and select the most appropriate for costing.

These alternatives are tabled and reviewed as follows:

Table 17: Alternative solutions.

	Description	**Advantages**	**Disadvantages**	**Progress /Reject**
1	Catchment management	Low capital cost, best long-term solution	Long term solution. Included in WINEP for peatland restoration, but timescale for improvements to stabilise DOC likely to be 10-20years; progress alongside all engineered options to secure sustainability of solution and reduce future OPEX/carbon.	No
2	Close Oldfield WTW and expand Sladen Valley WTW (DAF and RGF/Mn Contactors) by 12Ml/d and installation of a 24 Ml/d MIEX plant pre-treatment. (Arup study option1b)	Blending all waters together provides most operational flexibility MIEX+DAF proven effectiveness.	Complex as relies on a hydroturbine to recover power from transfer of water to and from Sladen. Planning and PR issues at Sladen. Risks and complications of transfer of raw and	No

			treated water. MIEX+DAF expensive opex and Capex combination (ranked 4-6 out of 6 for NPC in Arup study)	
3	Close Sladen Valley WTW, retain and refurbish the existing Oldfield works and install a new additional 14.5 Ml/d plant capacity at Oldfield WTW) (Arup study option 2a)	Blending all waters together provides most operational flexibility Low capital cost	Condition of existing Oldfield clarifiers is considered beyond repair and carries too high risk. Risks and complications of transfer of raw and treated water. Concerns over PR from closing Sladen valley.	No
4	Close Sladen Valley WTW and build a new 24Ml/d works at the Oldfield site (Arup study option 2b) + 12 Mld MIEX Plant	Blending all waters together provides most operational flexibility. Blanket clarifiers proven low capex/opex and robust for high coloured water. MIEX pre-treatment on the highest coloured water provides robustness.	Risks and complications of transfer of raw water from Sladen. Concerns over PR from closing Sladen valley.	Yes

3.2.7 Proposed Alternatives

The alternative to upgrading both Sladen Valley and Oldfield works is to move all the treatment to a single site which offers benefits in flexibility of managing and blending water and operating a single site, though incurs the additional complexity of transferring raw and treated water.

The proposed alternative is to close Sladen Valley and build a single new works at the Oldfield site. The works would be built adjacent to the existing works and comprise the following:

Raw and Treated Water transfer

- Replace Watersheddles main (4.1km, 400mm dia.)
- Transfer pipelines and pumping Raw water from Sladen to Oldfield (Combined Ponden and Lower Laithe flows) (2.6km, 400 dia).
- Treated water booster pumping (Oldfield to Lane End SRE) at Cob Hill.

Treatment process

- MIEX pre-treatment for 12 Mld
- 24 Mld Flat-bottomed Clarifiers
- 24Mld RGF and manganese contactors
- Washwater handling and recovery
- Chlorine contact tank
- Run to waste tank
- Treated Water Storage (18 Ml)
- New chemical storage and dosing (Lime, Hypo, MSP, Ferric)
- Demolish old works.

Reason for choice of proposed solution

At the current level of investigation, the costs of undertaking the combined solution outweigh the advantages. This is in large part due to the amount of network reinforcement required to restore the resilience of the system lost by closing one of the WTWs. In addition, Sladen Valley is a more modern WTW and would generate very significant write-off costs were it to be closed.

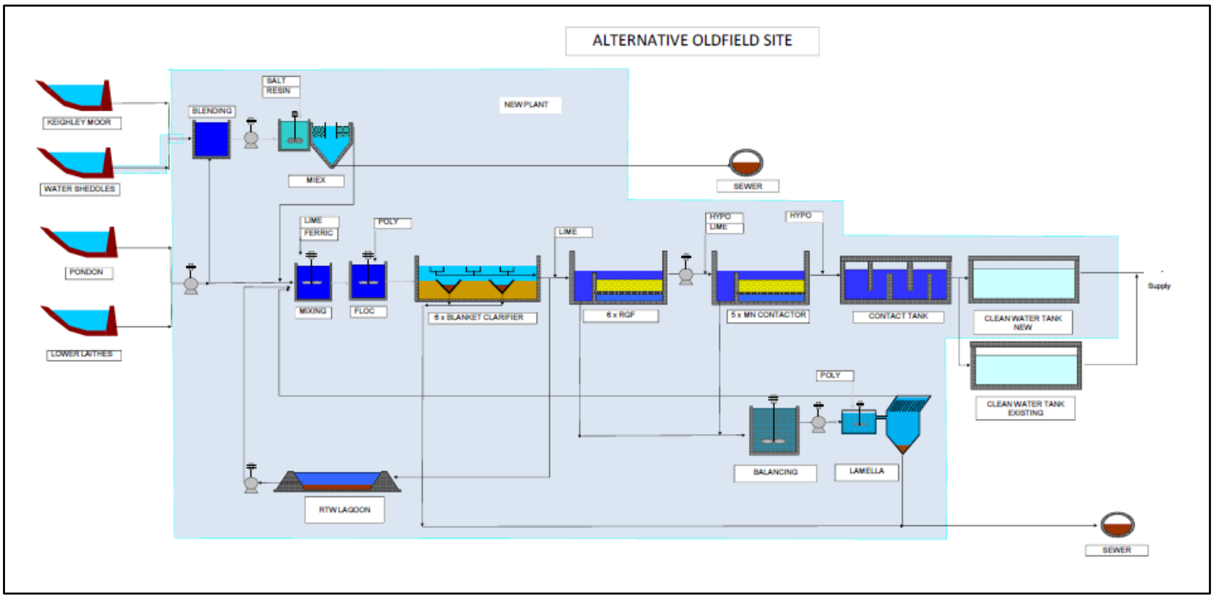

Figure. 20: Proposed solution - process schematic.

3.2.8 Catchment Solutions

Alongside delivery of the proposed engineered solution we are proposing additional catchment measures to build on activity undertaken in the current and prior AMP periods. This will focus, as described previously, on the development of a healthy community of bog plants which protect the peat from drying and thus exposure to oxygen. We believe that this activity is key to ensuring that the engineered WTW enhancements remain sustainable for the long-term, and hold out the prospect of being able to reduce the intensity of treatment over time, for example, by reducing the volume of water which has to pass through the ion-exchange process.

The Company is working with the EA in shaping the sites for inclusion in WINEP – the current list of sites associated with the raw water supplies to Oldfield WTW are shown in the table below.

Table 18: Catchments included in WINEP.

Driver Description	WINEPID	Function	RBD	Area	Water Company	Unique ID	Scheme Name	Waterbody	Waterbody ID	Water Body Type(s)	WFD Catchment	Driver Code
Drinking Water Protected Areas	YOR00154	WQ	Humber	Yorkshire	Yorkshire Water Service Ltd	7YW200098	Oldfield - Keighly Moor	North Beck from Source to River Worth	GB104027064230	River	Aire Middle	DrWPA_ND
Drinking Water Protected Areas	YOR00155	WQ	Humber	Yorkshire	Yorkshire Water Service Ltd	7YW200099	Oldfield - Watersheddles	Worth from Source to Bridgehouse Beck	GB104027064210	River	Aire Middle	DrWPA_ND

2.3 Sladen Valley WTW

2.3.1 Overview

Sladen Valley WTW is an aging asset, with a current maximum output of around 12Ml/d. It is one of the supplies to the Keighley area to the west of Bradford, with only limited support from other systems. Deterioration of the raw water quality in respect of organic colour now risks compliance with standards or regulatory requirements. The proposed PR19 scheme addresses both new quality obligations, and resolves other risks to enable the quality investment to perform satisfactorily. In addition, the scheme also incorporates significant base-maintenance investment to improve the overall resilience of the site, and aid recovery from failure.

Table 19: Scheme costs.

Site	Capex (£million)	Opex per annum (£million)
Sladen Valley WTW	£ 14.6	£ 0.2

Table 20: Alternative solution costs.

Site	Scheme	Technically Feasible	Risk Addressed	Lowest WLC
Sladen Valley - Chosen option	DOC I-Ex	Y	Y	N
Sladen Valley - Alternative	See combined solution	Y	PART	Y
	WLC assessment includes all base maintenance investment required to deliver scheme.			

Table 21: Overview of DWSP Risks to be addressed.

Risk	Solution
DBP risk – Reg26 compliance / Public Health impact / compliance risk	Install ion exchange DOC removal stage on raw water inlet (12Ml/d)
Aging	Installation of 2 new run to waste tanks (25Ml) and associated valves and control system
Turbidity risk – entering final stage of disinfection	Installation of run to waste system and improvements to resilience of key chemical dosing systems

1. Long term increase in colour trend in the catchment: **Oldfield - Drinking Water Quality (Biological & Chemical)**.
2. Max colour events more frequent: Sladen & Oldfield - **Drinking Water Quality (Biological & Chemical).**
3. Change in nature of DOC changing chemistry (hydrophilic/phobic): **Oldfield & Sladen - Drinking Water Quality (Biological & Chemical).**
4. Burst History of raw water main from Watersheddles IRE to WTW: **Oldfield - Water Supply Availability.**
5. Oldfield ageing plant - civils failures likely within 5-10 years - **Oldfield - Water Supply Availability.**

2.3.2 Detail of risks to be resolved

Colour / Regulation 26 compliance (DBPs)

High colour levels in the catchment (Ponden and Lower Laithe IREs). There has been a long-term increase in colour trend in these catchments and they have been subject to catchment management . Statistical analysis suggests that this trend, although slow, is continuing and therefore the risks from DBPs are increasing as a consequence.

It is noted and predicted that maximum colour events are becoming more frequent as a result of changes to land use and weather patterns. There is also a gradual change in the nature of DOC chemistry and the balance between hydrophilic & hydrophobic fractions resulting in increased risk of DBP formation over time.

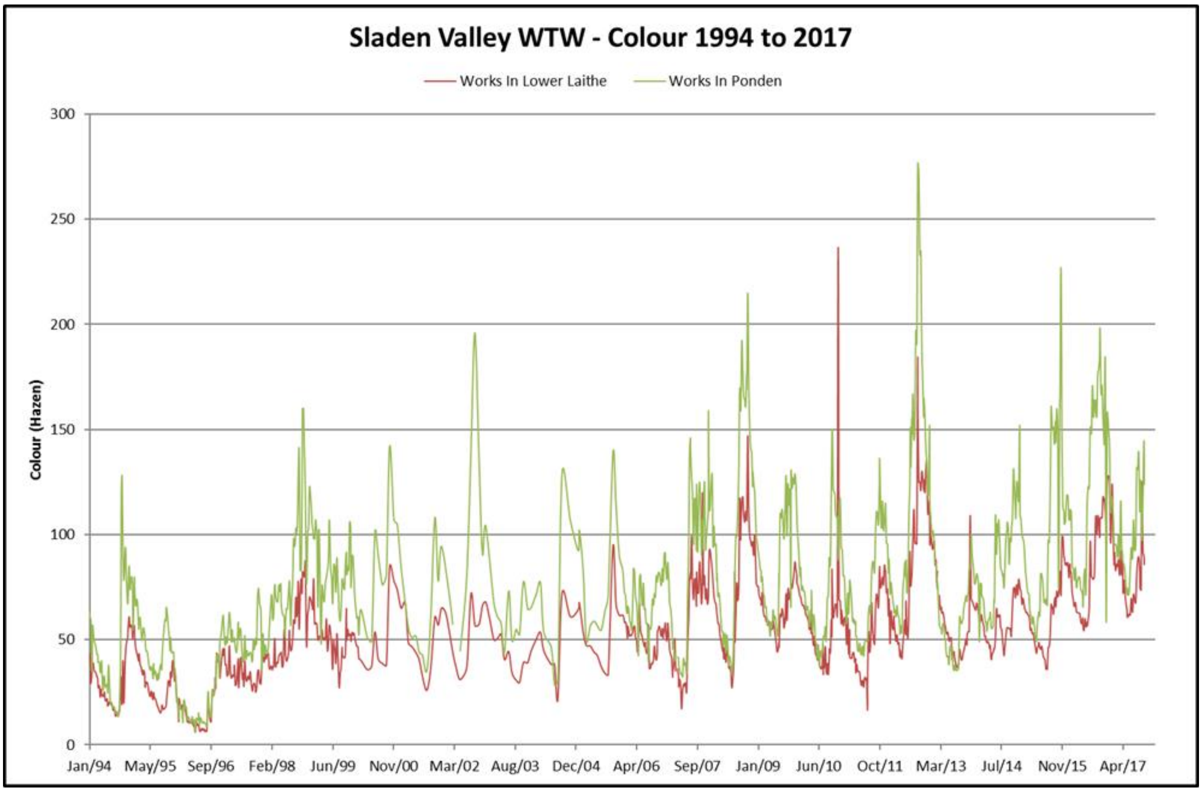

Figure. 21: Raw water colour at Sladen Valley WTW.

Table 22: Statistical analysis of colour trends at Sladen Valley WTW.

	1987 - 2015 Leeds	1998 to 2015 Leeds	1998 to 2015 Leeds		
	By Month	By Month	By Year		
Site	Median	Median	Max	Mean	Min
Sladen Valley - Combined		0.77	2.83	0.98	0.08
Sladen Valley - L-laith		0.51	1.92	0.67	0.08
Sladen Valley - Ponden		0.1	2.75	0.84	0.07

KEY:	Highly sig (@1% level)	Sig (@ 5% level)	Non sig

Although catchment activity has been undertaken in the current and previous AMPs the raw water is still deteriorating, albeit relatively slowly in recent years. We will continue to invest in the catchments to ensure the sustainablility of the solution proposed for the long-term. Both catchments are included in the current version of WINEP from the EA.

Table 23: THM results from associated WSZ.

WSZ	Year	Average
	2010	48.78
	2011	47.34
	2012	50.03
	2013	41.87
	2014	44.80
	2015	47.74
KEIGHLEY 2004 WSZ	2016	51.42

2.3.3 Site Resilience

Sladen Valley WTW has few engineering challenges which require resolution to assure the sites resilience and resistance to failure. Within the supply system there is limited water storage which limits the ability to shut the site down whilst maintaining supplies.

2.3.4 Proposed solutions

The solutions proposed are targeted at resolution of the risks as described above and include the following key enhancements and additions to the existing processes:

Proposed solution - Colour/DBPs

The installation of an ion exchange process to reduce the colour/DOC loading on the coagulation process is the most logical approach to reducing DBP risk in treated water.

The company experience is that, although the ion-exchange process typically removes around 30% of influent DOC, it reduces THM Formation Potential more significantly as it removes the DOC fractions which are not easily removed by coagulation. It therefore is highly effective in reducing DBP formation overall. We have been operating processes of this type for around ten years at three sites, and are currently installing a fourth.

Most of the installation of this process is made above ground, in stainless steel or similar materials. This avoids the commitment in long asset life equipment which, were catchment management to be successful over time, would become redundant. Thus, although treatment investment in now considered unavoidable, the process units could be removed and recycled effectively or deployed elsewhere.

The proposed locations for additional or re-located process units are shown in figure 22 below:

Figure. 22: Sladen Valley - Proposed site overview.

Proposed location of new or relocated process units – solid lines

- An ion-exchange process, designed for DOC removal (for example MIEX) to treat the full flow to site from the raw water sources (~12Ml/d). This will be located adjacent to the existing WTW.

The process diagram below demonstrates the relative ease of integration of the proposed solution into the existing process and site.

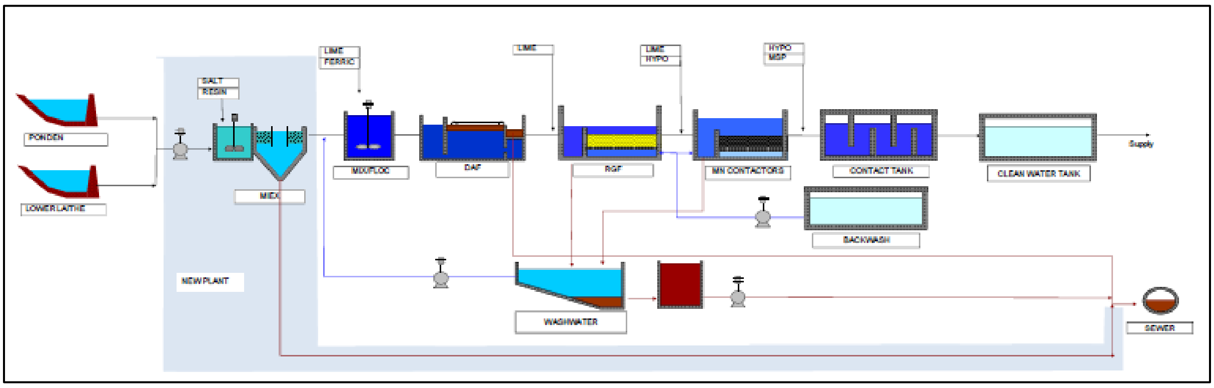

Figure. 23: Proposed solution - process schematic.

By intercepting the raw water mains at the inlet it is likely that there is sufficient head available to drive the raw water into the ion-exchange facility; from there the partially treated water follows the existing hydraulic pathway through the subsequent processes and on into the treated water tanks.

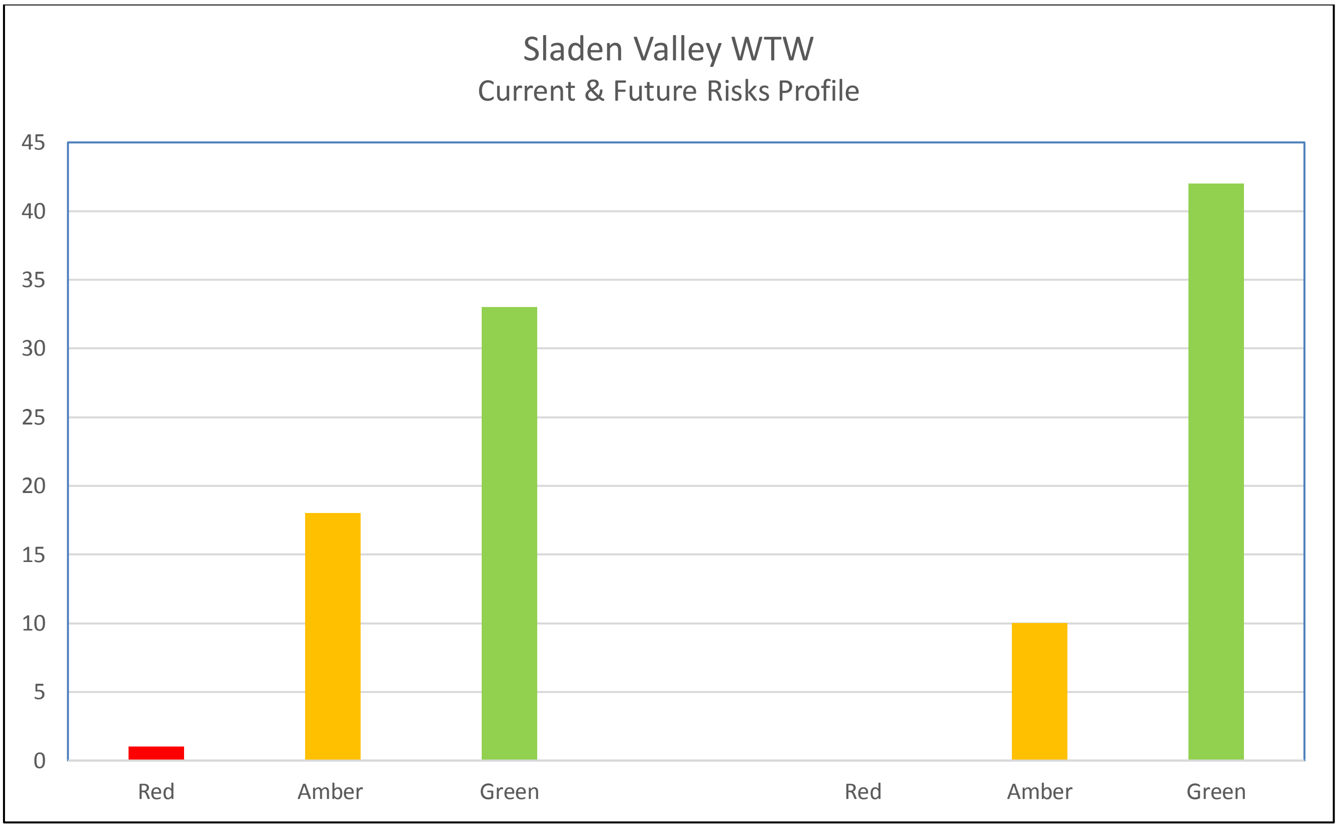

Figure. 24: DWSP change in risk position.

2.3.5 Other risks to be resolved:

Alternative solutions considered

As part of the workshop approach to identifying the most appropriate solution a number of alternative solutions or partial solutions were identified. These provided less certainty around resolving the risks either individually or in combination, and were therefore rejected.

The potential alternatives are as follows, and include options reviewed in pre-workshops.

Arup conducted a feasibility study into the Keighley/Bradford Water supply system (WTW and Network Optimisation study). The study included a review of Sladen Valley and Oldfield and also the wider network. This provided options and recommendations for individual works upgrades and combining of the WTW sites. The outputs of these studies and recommendations have been reviewed to determine potential alternatives to the main proposed solution and select the most appropriate for costing.

These alternatives are tabled and reviewed as follows:

Table 24: Alternative solutions.

	Description	Advantages	Disadvantages	Progress
1	Catchment management	Low capital cost, best long-term solution	Long term solution. Included in WINEP for peatland restoration, but timescale for improvements to stabilise DOC likely to be 10-20years; progress alongside all engineered options to secure sustainability of solution and reduce future OPEX/carbon.	No
2	Close Oldfield WTW and expand Sladen Valley WTW (DAF and RGF/Mn Contactors) by 12Ml/d and installation of a 24 Ml/d MIEX plant pre-treatment. (Arup study option1b)	Blending all waters together provides most operational flexibility MIEX+DAF proven effectiveness.	Complex as relies on a hydroturbine to recover power from transfer of water to and from Sladen. Planning and PR issues at Sladen. Risks and complications of transfer of raw and treated water. MIEX+DAF expensive opex and Capex combination (ranked 4-6 out of 6 for NPC in Arup study)	No
3	Close Sladen Valley WTW, retain and refurbish the existing Oldfield works and install a new additional 14.5 Ml/d plant capacity at	Blending all waters together provides most operational flexibility Low capital cost	Condition of existing Oldfield clarifiers is considered beyond repair and carries too high risk.	No

	Oldfield WTW) (Arup study option 2a)		Risks and complications of transfer of raw and treated water. Concerns over PR from closing Sladen Valley.	
4	Close Sladen Valley WTW and build a new 24Ml/d works at the Oldfield site (Arup study option 2b) + 12 Mld MIEX Plant	Blending all waters together provides most operational flexibility. Blanket clarifiers proven low capex/opex and robust for high coloured water. MIEX pre-treatment on the highest coloured water provides robustness.	Risks and complications of transfer of raw water from Sladen Valley. Concerns over PR from closing Sladen Valley.	Yes

2.3.6 Proposed Alternatives

The alternative to upgrading both works is to move all the treatment to a single site which offers benefits in flexibility of managing and blending water and operating a single site, though incurs the additional complexity of transferring raw and treated water.

The proposed alternative is to close Sladen Valley and build a single new works at the Oldfield site. The works would be built adjacent to the existing works and comprise of the following:

Raw and Treated Water transfer

- Replace Watersheddles main (4.1km, 400mm dia.).
- Transfer pipelines and pumping Raw water from Sladen to Oldfield (Combined Ponden and LL flows) (2.6km, 400 dia).
- Treated water booster pumping (Oldfield to lane end) at Cob Hill.

Treatment process

- MIEX pre-treatment for 12 Mld
- 24 Mld Flat bottomed Clarifiers

- 24Mld RGF and Manganese contactors
- Washwater handling and recovery
- Chlorine contact tank
- Run to waste tank
- Treated Water Storage (18 Ml)
- New chemical storage and dosing (Lime, Hypo, MSP, Ferric)
- Demolish old works.
- A flow diagram and outline design sketch are provided in Appendix A

Table 25: Alternative solution for Sladen Valley & Oldfield WTWs.

Site	Scheme	Technically Feasible	Risk Addressed	Lowest WLC
Oldfield & Sladen	See individual sites	Y	Y	N
Oldfield & Sladen - Alternative	Combined new build – 24Ml/d @ Oldfield 0 DOC I-Ex / Clar'r / RGF / Mn Ctr / Cl CT	Y	Y but new resilience risk created	Y
	WLC assessment includes all base maintenance investment required to deliver scheme.			

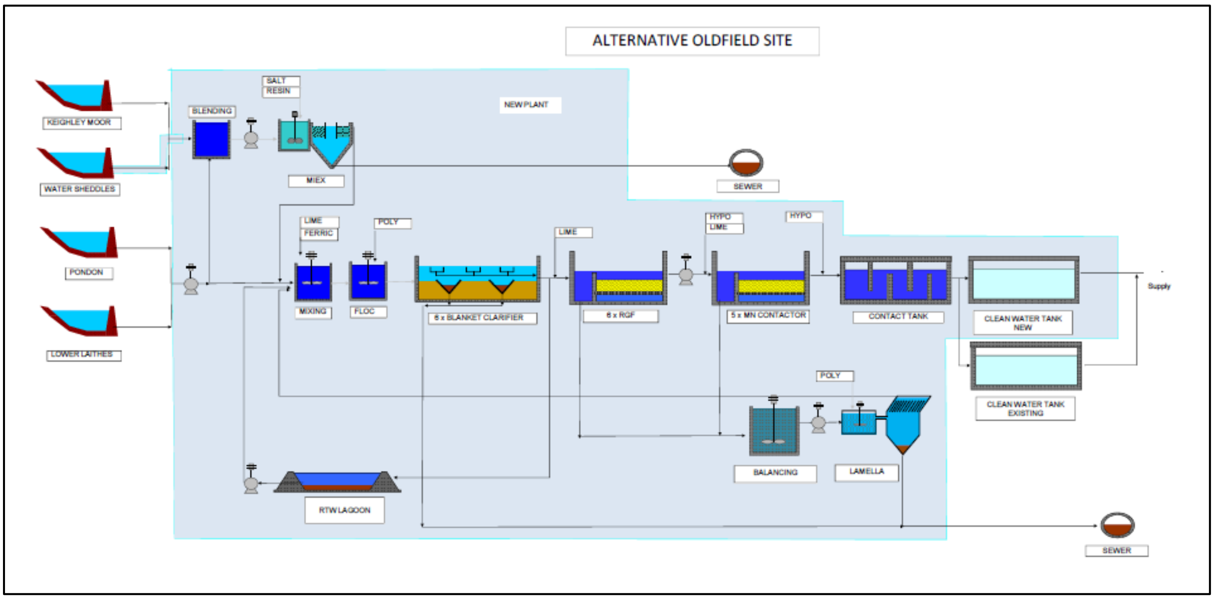

Figure. 25: Proposed solution - Process schematic.

2.3.7 Catchment Solutions

Alongside delivery of the proposed engineered solution we are proposing additional catchment measures to build on activity undertaken in the current and prior AMP periods. This will focus, as described previously, on the development of a healthy community of bog plants which protect the peat from drying and thus exposure to oxygen. We believe that this activity is key to ensuring that the engineered WTW enhancements remain sustainable for the long-term, and hold out the prospect of being able to reduce the intensity of treatment over time, for example by reducing the volume of water which has to pass through the ion-exchange process.

Ponden and Lower Laithe catchments have been included in the Water Industry National Environment Programme (WINEP) to fund further repair activities to SSSI areas. The action plan is to complete repair work on Ponden and Lower Laithe with bare peat re-vegetation, grip and gully blocking and stock removal. Management work is to be completed over a 15-year period.

2.4 Fixby WTW

2.4.1 Overview

Fixby WTW was commissioned in its current form in 1992, with a current maximum output of around 30Ml/d. It is one of the supplies to the Wakefield area to the southeEast of Leeds, but also supplies a significant local area, with only limited support from other systems. Deterioration of the raw water quality in respect of organic colour now risks compliance with standards or regulatory requirements. The proposed PR19 scheme addresses both new quality obligations, and resolves other risks to enable the quality investment to perform satisfactorily. In addition, the scheme also incorporates significant base-maintenance investment to improve the overall resilience of the site, and aid recovery from failure.

Table 26: Scheme costs.

Site	Capex (£million)	Opex per annum (£million)
Fixby WTW	£ 5.6	£ 0.04

Table 27: Alternative solution costs.

Site	Scheme	Technically Feasible	Risk Addressed	Lowest WLC
Fixby - Chosen	DAF refurb / Add'l RGF	Y	Y	Y
Fixby - Alternative	DOC I-Ex / DAF refurb / Add'l RGF	Y	Y	N
	WLC assessment includes all base maintenance investment required to deliver scheme.			

Table 28: Overview of DWSP Risks to be addressed.

Risk	Solution	
DBP risk – Reg26 compliance / Public Health impact /	Upgrade DAF system to latest design (Saturation system / Nozzle design /	

compliance risk – due to raw water deterioration	desludging system	
Insufficient RGF capacity to cope with full flow at increased solids loading due to colour increase in raw water	Install 3 new RGFs – to bring filtration rate to standard values following a DAF clarification system	
Turbidity risk – entering final stage of disinfection	Enhancements to existing run to waste system and complete separation from DWW system.	

1. Long term increase in colour trend in the catchment: **- Drinking Water Quality (Biological & Chemical).**
2. Max colour events more frequent: **- Drinking Water Quality (Biological & Chemical).**
3. Change in nature of DOC changing chemistry (hydrophilic/phobic): - **Drinking Water Quality (Biological & Chemical).**

- DAF refurbishment (nozzles, scrapers, saturators, compressors)
- RGF refurb and 3 new RGF and connection to ancillaries. (demolish old clarifiers)
- New Manganese contactor splitter tank
- New lamella DWW system
- Poly dosing for RGF and New Lamella
- Post-manganese contactor run to waste to tank
- Caustic dosing at works outlet

2.4.2 Detail of risks to be resolved

Colour / Regulation 26 compliance (DBPs)

High colour levels in the catchment (Baitings and Ringstone IREs). There has been a long-term increase in the colour trends in these catchments and they have been subject to catchment management. Statistical analysis suggests that this trend, which is highly significant, is continuing and therefore the risks from DBPs are increasing as a consequence.

It is noted and predicted that maximum colour events are becoming more frequent as a result of changes to land use and weather patterns. There is also a gradual change in the nature of DOC chemistry and the balance between hydrophilic & hydrophobic fractions resulting in increased risk of DBP formation over time.

At the time of WTW design the raw water average colour was around 30°H, and the maximum 80°H; currently the average is 85°H, and the maximum 155°H.

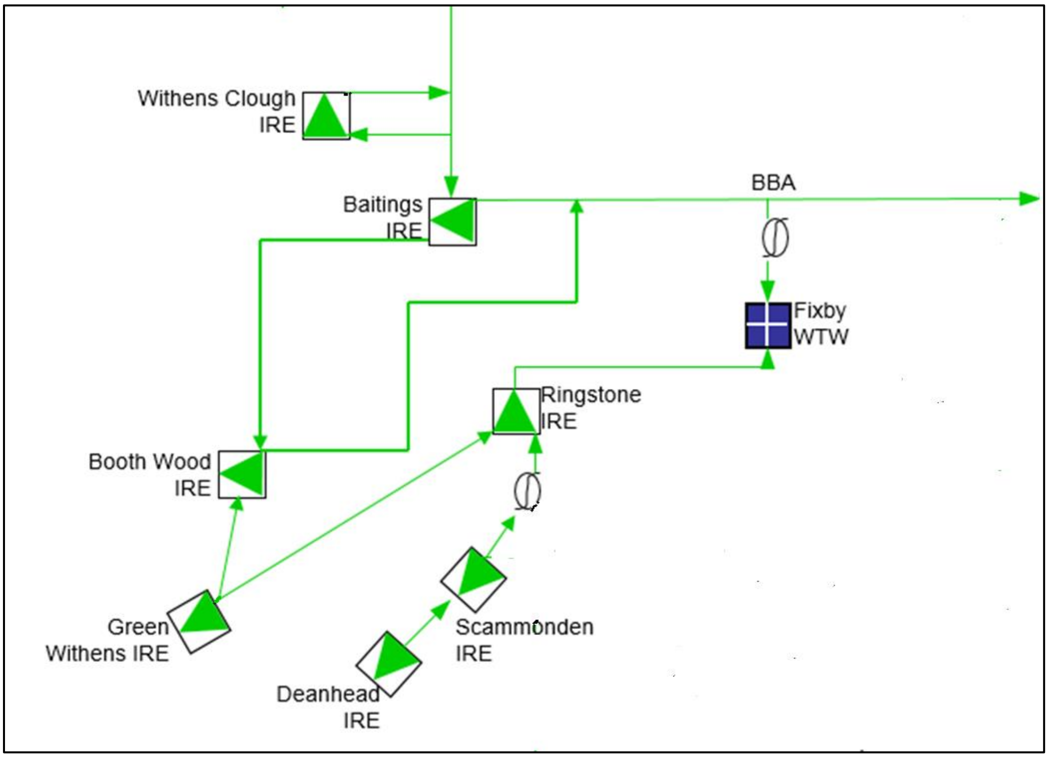

Figure. 26: Fixby raw water supply schematic.

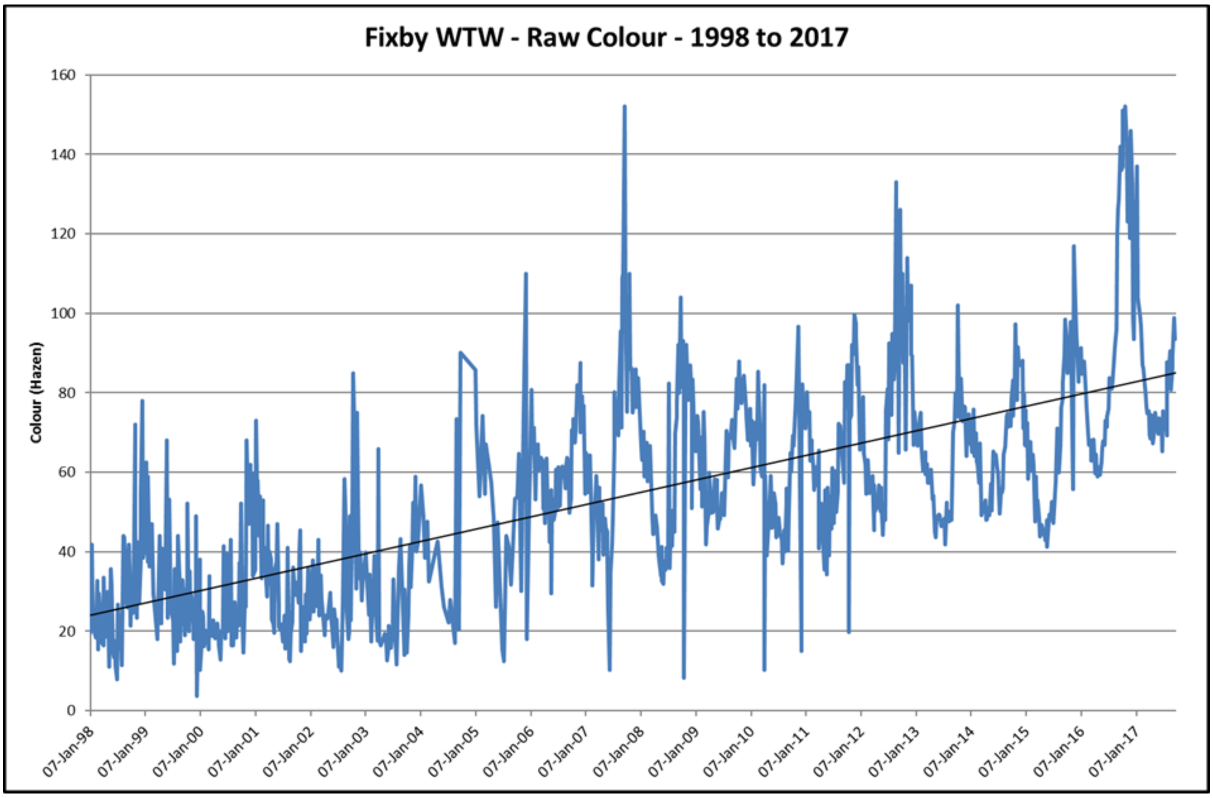

Figure. 27: Fixby raw water colour trend.

Table 29: Statistical analysis of raw water colour at Fixby WTW.

	JAN 1998+							
	By MONTH				By YEAR			
Site	Max	Mean	Median	Min	Max	Mean	Median	Min
Fixby	2.488	2.59	2.614	2.75	2.093	2.682	2.68	2.429

	JAN 2004+							
	By MONTH				By YEAR			
Site	Max	Mean	Median	Min	Max	Mean	Median	Min
Fixby	1.22	1.448	1.378	1.629	0.265	1.566	0.93	3.446

KEY:	Highly sig (@1% level)	Sig (@ 5% level)	Non sig

Although catchment activity has been undertaken in the current and previous AMPs the raw water is still deteriorating at a significant rate. We will continue to invest in the catchments to ensure the sustainablility of the solution proposed for the long-term. All catchments are included in the current version of WINEP from the EA.

Table 30: Zone THM's 2007 to 2017 RR coded samples only.

Fed from Fixby

Zone	Year	THM Total (µg/l)			
		Total No of samples	Max	Min	Average
BRIGHOUSE 2004 WSZ	2007	9	64	39.7	50.678
	2008	8	58.9	27.7	41.913
	2009	8	71.2	25.1	43.900
	2010	8	54.9	25.6	38.913
	2011	8	52.5	29.8	40.838
	2012	8	66.2	25.7	39.850
	2013	8	52.61	18.5	34.453
	2014	8	54.5	25.4	39.155
	2015	8	54.98	26.83	41.735
	2016	8	56.94	21.93	40.444
	2017	4	54.46	32.83	41.900
WAKEFIELD CITY S 2008 WSZ	2007	12	64.2	28.5	42.150
	2008	7	58.6	29.7	37.243
	2009	6	47.3	1	35.533
	2010	9	54.8	28.8	36.711
	2011	8	68.8	19.3	38.013
	2012	8	57.7	27.1	39.975
	2013	8	58.99	22	33.110
	2014	8	62.77	27.31	39.953
	2015	8	62.43	31.91	41.509
	2016	8	66.17	27.68	37.128
	2017	4	64.09	32.64	45.888

2.4.3 Site Resilience

Fixby WTW has a number of engineering challenges which require resolution to assure the site is resilient and resistant to failure. Within the supply system there are reasonable levels of water storage which limits the risk of loss of supply, and most of the supply area can be supported from other sources but local supplies cannot be support. This gives limited ability to shut the site down whilst maintaining supplies; therefore, additional run to waste capacity is required to aid recovery from site shutdowns and protect treated water quality.

2.4.4 Proposed solutions

The solutions proposed are targeted at resolution of the risks as described above. It includes the following key enhancements and additions to the existing processes:

Proposed solution - Colour/DBPs

Given the slightly lower levels of colour the enhancement of the dissolved air flotation (DAF) processes to improve the capture of solids, rather than installation ion exchange, is proposed to reduce the impact of colour/DOC loading on the clarification process is the most logical approach to reducing DBP risk in treated water.

In addition, the RGFs at the site are operating at a higher filtration rate than we would currently design to follow a DAF clarification process. With the additional solids carry-over this results in a significant reduction in works output when the raw water quality deteriorates. This is not sustainable and leads to a miss-match within our long-term water resource management plan (WRMP) which requires resolution.

We also propose significant changes to the existing dirty wash water (DWW) treatment process and the run to waste system on the site which will reduce the risk of water quality deterioration impact on customers.
The proposed locations for additional or re-located process units are shown in figure 28 below:

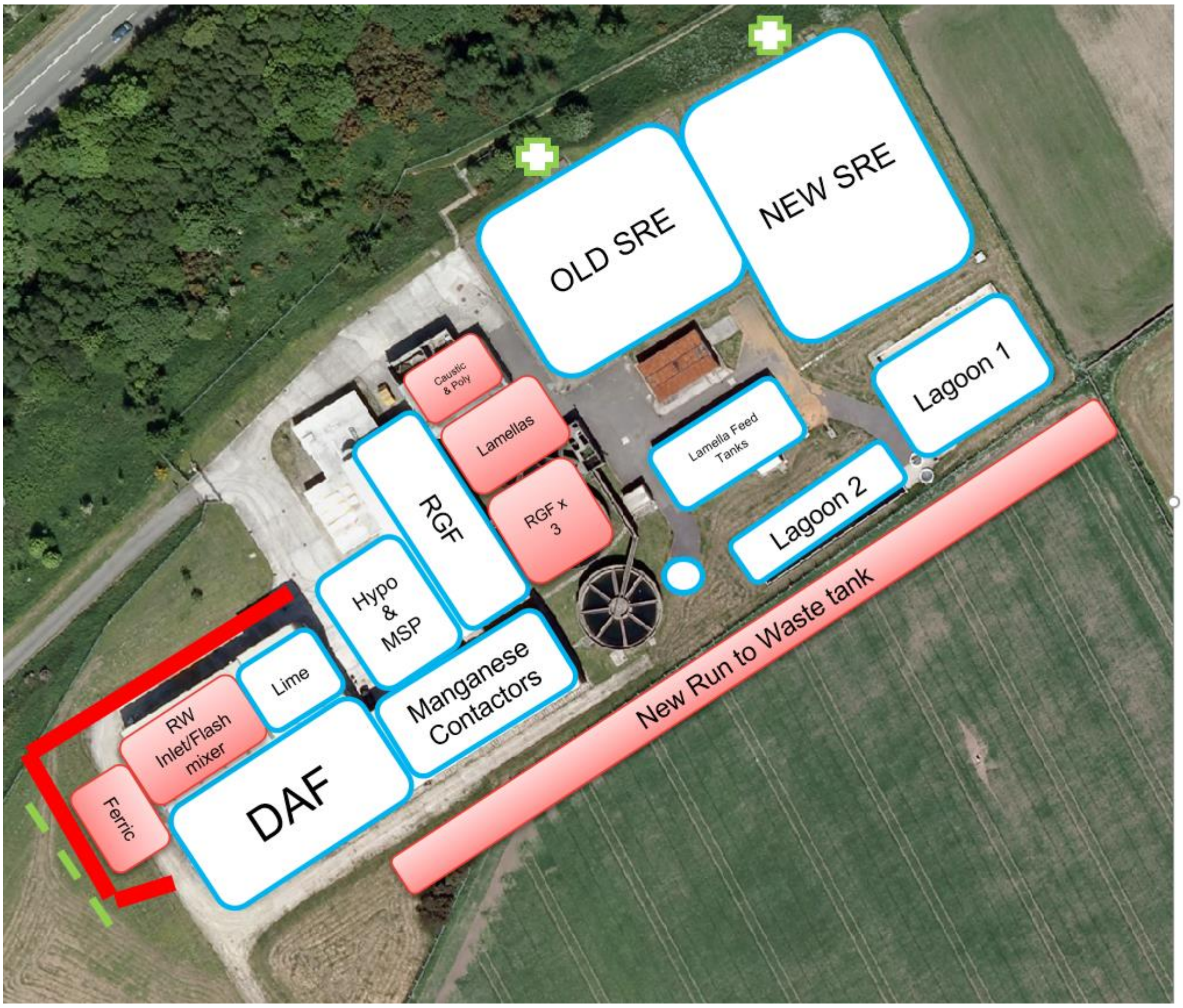

Figure. 28: Proposed location of new or relocated process units – red lines / existing process units – blue line.

The process diagram below demonstrates the relative ease of integration of the proposed solution into the existing process and site.

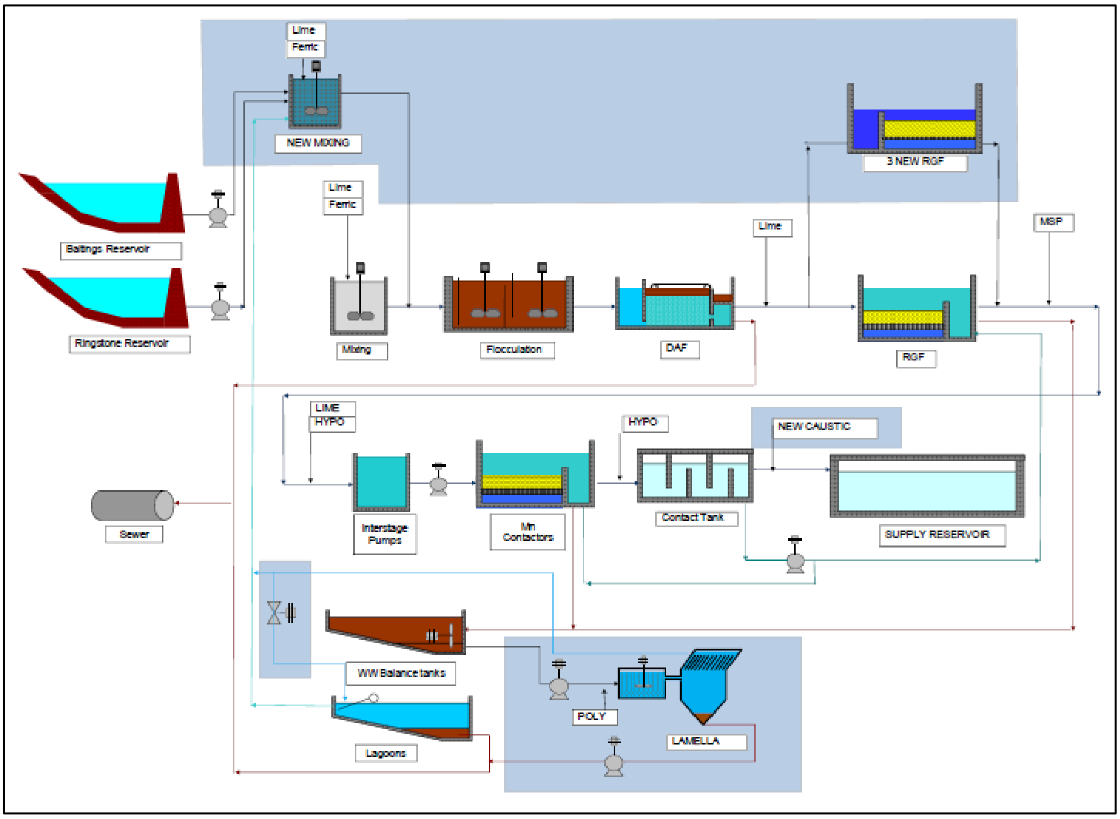

Figure. 29: Proposed solution process schematic.

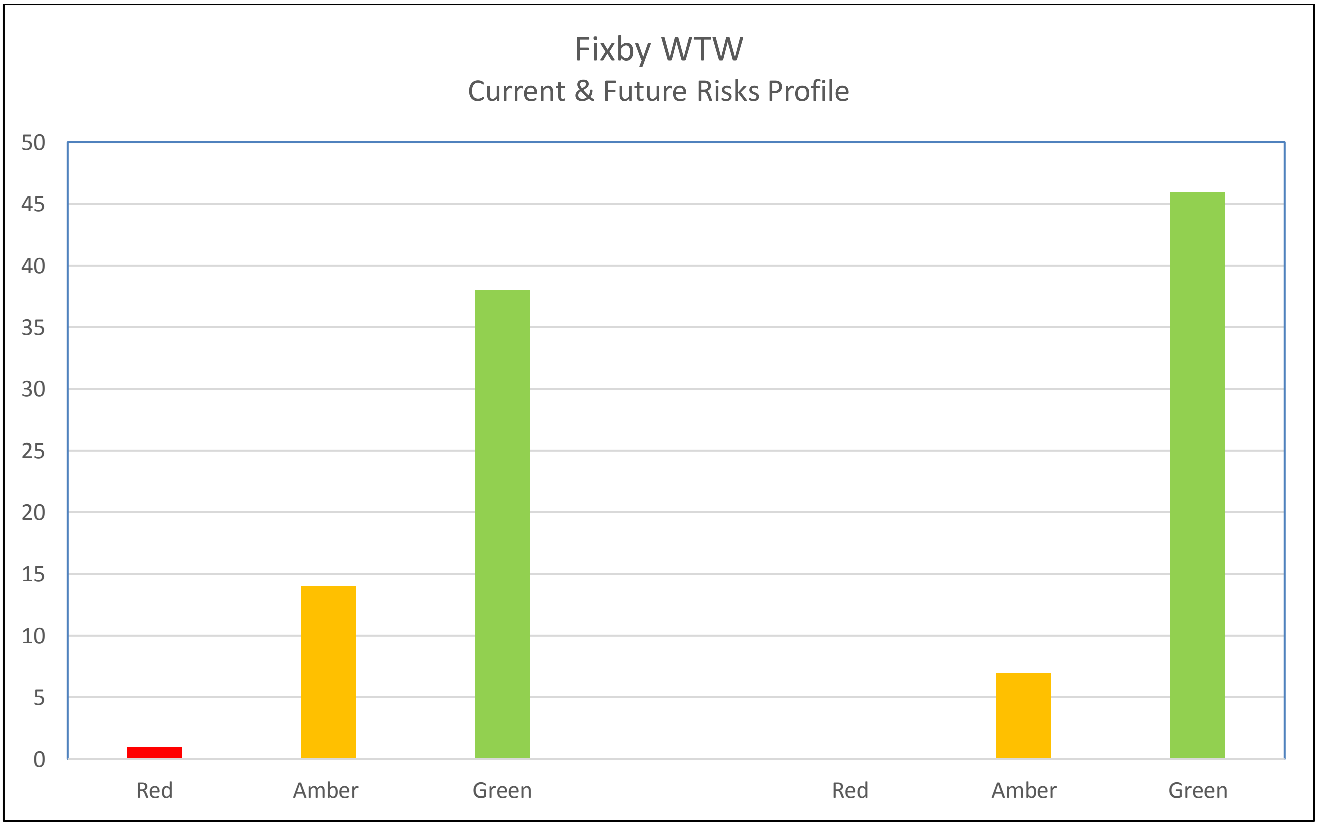

Figure. 30: DWSP change in risk position.

2.4.5 Alternative solutions considered

As part of the workshop approach to identifying the most appropriate solution a number of alternative solutions or partial solutions were identified. These provided less certainty around resolving the risks either individually or in combination, and were therefore rejected.

The potential alternatives are as follows, and include options reviewed in pre-workshops.

Table 31: Alternative solutions.

	Description	Advantages	Disadvantages	Progress
1	Catchment management	Low capital cost, best long-term solution	Long term solution. Included in WINEP for peatland restoration, but timescale for improvements to stabilise DOC likely to be 10-20years; progress alongside all engineered options to secure sustainability of solution and reduce future OPEX/carbon.	No
2	MIEX or alternative Ion exchange. + DAF upgrade. Additional RGF	Will reduce coagulant dose and ensure good DAF performance Reduces solids load on existing process, strengthens floc, reduces filter breakthrough and increases filter run time Improved DAF performance reduces impact on RGF. Reduces THM's by enhanced removal of DOC	High Opex cost. Brine disposal (site has a sewer).	Yes
3	Change Raw water blend	Simple low cost	Insufficient data on quality and relative treatability of Baitings	No

			and Ringstone sources. Colour difference is not huge. Ringstone is base flow gravity to 18.5 Mld (pumped up to 22.5 Mld) and preferred. Baitings 8 Mld pumped (not preferred from treatability perspective).	
5	Nano filtration for removal of colour	Effective at removing DBP precursors.	Untested in YWS and trialling is not possible within the current timeframes. High opex cost and risk (membrane life, flux).	No

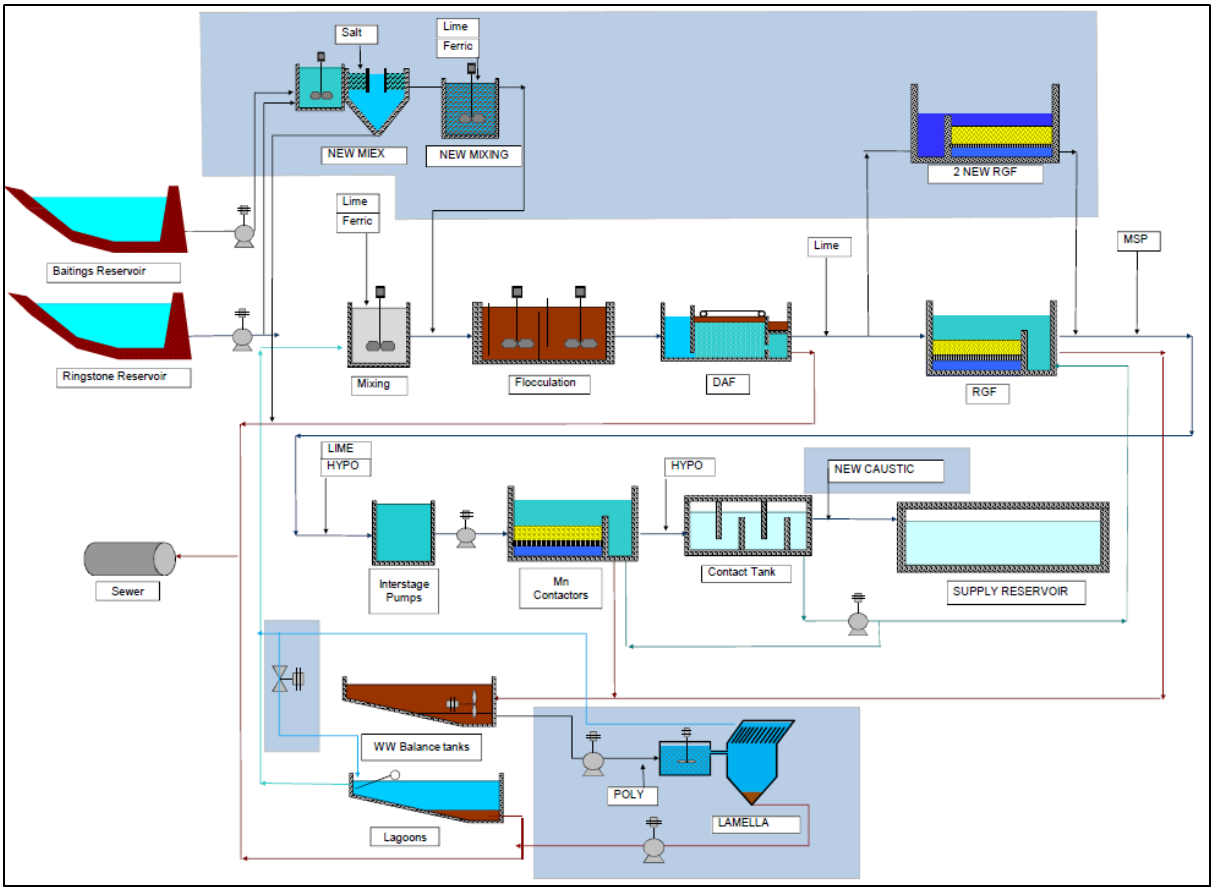

Figure. 31: Alternative solution - Process schematic.

2.4.6 Catchment Solutions

Alongside delivery of the proposed engineered solution we are proposing additional catchment measures to build on activity undertaken in the current and prior AMP periods. This will focus, as described previously, on the development of a healthy community of bog plants which protect the peat from drying and thus exposure to oxygen. We believe that this activity is key to ensuring that the engineered WTW enhancements remain sustainable for the long-term, and hold out the prospect of being able to reduce the intensity of treatment over time, for example, by reducing the volume of water which has to pass through the ion-exchange process.

The Company is working with the EA in shaping the sites for inclusion in WINEP – the current list of sites associated with the raw water supplies to Fixby WTW are shown in the table below.

Table 32: Catchments included in WINEP.

Driver Description	WINEPID	Function	RBD	Area	Water Company	Unique ID	Scheme Name	Waterbody	Waterbody ID	Water Body Type(s)	WFD Catchment	Driver Code
Drinking Water Protected Areas	YOR00188	WQ	Humber	Yorkshire	Yorkshire Water Service Ltd	7YW200132	Rishworth / Green Withens/ Boothwood	Booth Dean Clough from Source to River Ryburn	GB1040270 62520	River	Calder Middle	DrWPA_ND
Drinking Water Protected Areas	YOR00189	WQ	Humber	Yorkshire	Yorkshire Water Service Ltd	7YW200133	Baitings	Ryburn from Source to Booth Dean Clough	GB1040270 62540	River	Calder Middle	DrWPA_ND

2.5 Embsay WTW

2.5.1 Overview

Embsay WTW is designed to supply a maximum of 24 Ml/d. It typically treats 18 Ml/d and is located in the Yorkshire Dales National Park. It is the sole supply for the majority of the Western Dales, Skipton, Grassington and Barnoldswick. If the site fails approximately 10% of demand can be supplied from the adjoining Keighley WSS. Embsay is the only remaining Pennine WTW not to have manganese contactors. Manganese is therefore removed on the RGFs with prior chlorine dosing and pH adjustment. This increases the risk of DBP/THM formation, although THMs are minimised in distribution by chloramination.

Table 33: Scheme costs.

Site	Capex (£million)	Opex per annum (£million)
Embsay WTW	£ 8.0	£ 0.1

Table 34: Alternative scheme costs.

Site	Scheme	Technically Feasible	Risk Addressed	Lowest WLC
Embsay - Chosen	Mn contactors / new contact tank / run to waste	Y	Y	Y
Embsay - Alternative	I-Ex / new contact tank / run to waste	Y	Y	N
	WLC assessment includes all base maintenance investment required to deliver scheme.			

Table 35: Key Risks to be addressed.

Risk	Solution
DBP risk – Reg26 compliance / Public Health impact / compliance risk	Install manganese contactors for full flow (24Ml/d); move point of chlorination/pH correction downstream of RGFs
Deterioration of existing contact facility	Installation of new asset standard compliant contact facility
Turbidity risk – entering final stage of disinfection	Installation of run/start-up to waste system (2.3Ml) and associated valves and control system

2.5.2 Detail of risks to be resolved

The most significant risks and issues highlighted are as follows:

Change in nature of Colour / DOC - changing chemistry of organic peat-derived carbon and changes to land use leading to higher colour of raw water and increased frequency of peaks poses additional threats to compliance with Reg 26 – minimising DBP formation.

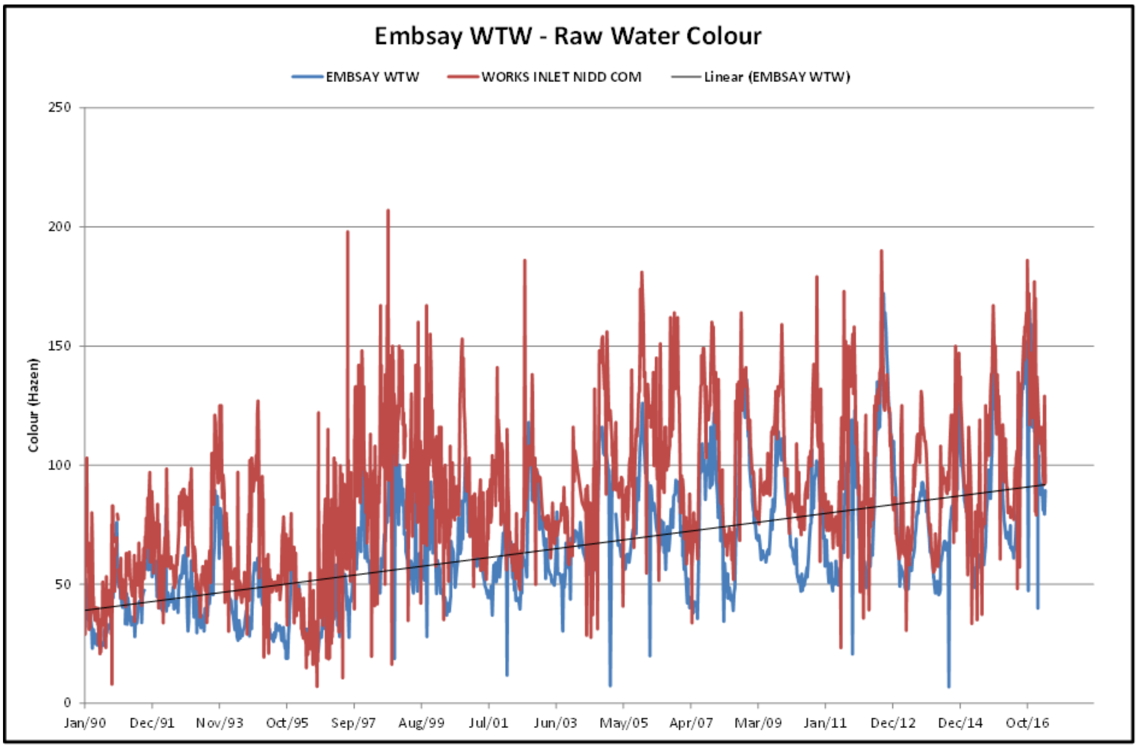

Figure. 32: Embsay WTW raw water colour trend.

The current slow rate of deterioration is not so pronounced as to require pre-treatment using a DOC removal ion-exchange process. We have considerable experience of the installation of manganese contactors as a means of reducing the risk of DBP formation, without the significant operational costs of ion-exchange. This approach allows the point of chlorination to be moved downstream of RGF solids removal stage, and avoids chlorine interacting with the retained solids on the filters.

Table 36: THM results in WSZ.

Average of Trihalomethanes total µg/l				
	2014	**2015**	**2016**	**2017**
SKIPTON/CRAVEN 2015 WSZ	35.16	37.26	32.13	34.61

Contact tank life expired and configuration unsuitable - a regulatory detection of *Clostridia perfringens* in January 2017 prompted an overnight shutdown of the WTW to inspect the contact tank which is located under the RGFs. This identified a leak into the structure, and that the condition of the concrete walls is poor. The contact tank is a single compartment and cannot be repaired for the long term within the timescales of a shutdown (max 12 hours). The Company has committed to investigate solutions to resolve the risk in the short & medium terms.

Single filter works - Embsay is the only Pennine source works that does not have secondary filtration for manganese removal. Consequently, chlorination is carried out prior to RGFs to remove Manganese. This increases THM formation and is currently mitigated by chloraminating the outlet supply. However, this process does not adequately satisfy the requirements of Reg 26 to "minimise disinfection by-products and their precursors". We previously proposed such a scheme in PR09, but subsequently withdrew the scheme and returned the funds to customers as it believed that a sustainable change in the quality of raw water had occurred. However, some years later, raw water conditions had returned to their previous state. It is now believed that the prior change was as a result of scour releases from Embsay IRE during Reservoir Safety works which required the level to be maintained significantly lower than usual. This would have the effect of reducing metals levels, but is not sustainable in the long-term.

As we are now targeting significantly lower levels of customer contacts and improved compliance for distribution it is now time to reduce the ex-works manganese concentrations to prevent the build-up of risk within the trunk main.

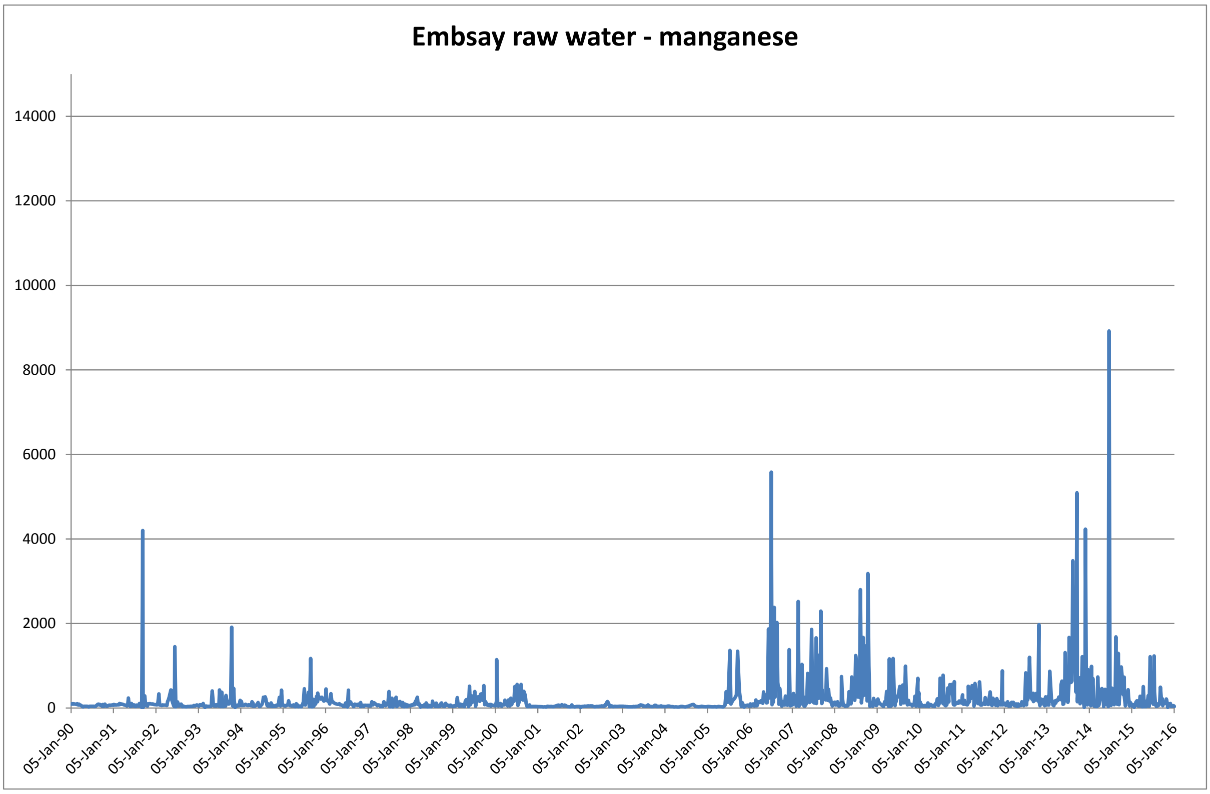

Figure. 33: Embsay raw water manganese trend.

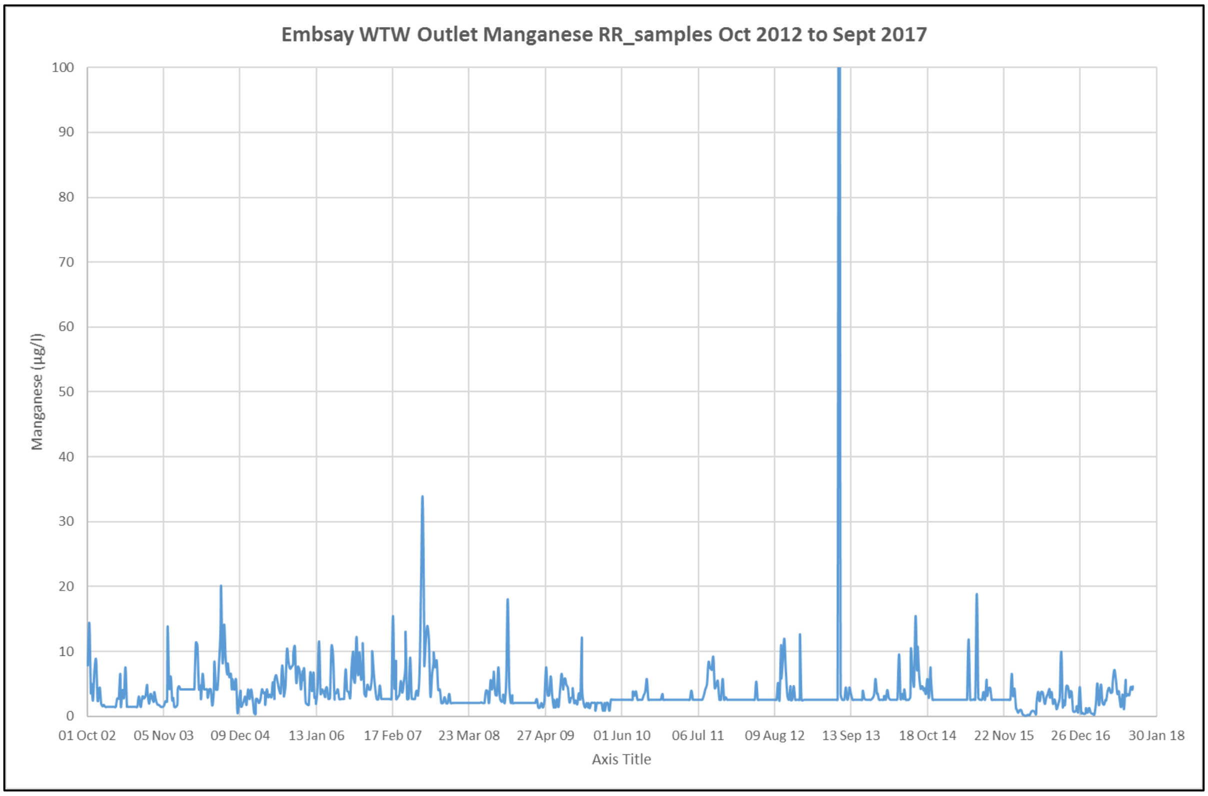

Figure. 34: Embsay WTW treated manganese trend.

Lack of run to waste system - Following the installation of automated shutdown the WTW shuts down infrequently, but sufficiently often to require a Run to Waste facility. Currently the only options are to overflow to the local beck from a number of different points within the WTW.

Water supply resilience - Embsay is effectively a stand-alone WTW with only minimal support potentially available from the adjacent Keighley WSZ which has its own constraints. The on-site Service Reservoirs hold a combined total of 19 Ml when full, providing between 18 and 24 hours supply. The provision of start/run to waste facilities will improve the ability to prevent water quality deterioration impacting customers and speed the start-up of the site following shutdowns.

The above proposals increase the inherent resilience of the site. Currently no specific proposals are in place to provide alternative supplies from adjacent areas but as part of our overall approach to improving resilience within AMP7 these options are being reviewed and prioritised.

Figure. 35: Embsay WTW site overview.

2.5.3 Proposed solutions

The solution proposed is targeted at resolution of the risks as described above. It includes the following key enhancements and additions to the existing processes. The proposed locations for additional or re-located process units are shown in figure 36 below:

Single filter works – add further stage

- Installation of new inter-stage pumps required to lift 1000m^3/hr by up to 5m.
- Modifications to RGFs to recirculate "return to service flow" to head of works or RGF inlet channel.
- Provide 2nd stage of filtration with a maximum filtration rate of 18m/hr. 5 contactors required; this will also require a new clean water backwash tanks for RGFs and Mn contactors, complete with new clean water backwash tank (supplied from chlorinated and Mn treated flow), backwash pumps (with VSDs to wash both RGFs and contactors), air blowers (to serve both RGFs and contactors).
- Dirty wash water from contactors to be returned to existing washwater channel and dirty wash water tanks.
- The hypochlorite dosing point will be moved from the inlet to the RGF to the inlet to the new Mn contactors to avoid chlorination of retained floc.

Contact tank life expired and configuration unsuitable – the scheme will provide: -

- A new dual compartment contact tank, approx. 700m^3 fixed-weir, baffled contact tank. Equivalent to 233m^2 x 3m deep.

- Relocation of associated chemical dosing, sampling lines and instrumentation. The single outlet main of 700mm diameter will be connected back into the existing twin 450mm outlet mains.

The existing contact tank is a single compartment and cannot be repaired for the long term within the timescales of a routine shutdown (max 12 hours). The Company has committed to investigate solutions to resolve the risk in the short & medium terms.

Lack of run to waste system - Following the installation of automated shutdown the WTW shuts down infrequently but sufficiently often to require a RTW facility. Currently the only options are to overflow to the local beck from a number of different points within the WTW which is an emergency facility only with the EA. The scheme proposes the installation of: -

- A new Start/Run to Waste tank located in area adjacent to existing service reservoirs on site (space is limited due to the steep gradients around the site).
- Connecting 700mm pipework from overflow post-RGF PS sump and outlet mains near to entrance to WTW. The system will provide around 4 hours of storage at a minimum flow of 13 Ml/d. The is equivalent to a tank size of roughly 25x23x4m (2300m^3).
- Connection pipework and return WPS will be sized to empty tank at a rate not greater than 10% of WTW flow - 1,800m^3/hr - to head of works.

Water supply resilience - Embsay is effectively a stand-alone WTW with only minimal support potentially available from the adjacent Keighley WSS. The on-site Service Reservoirs hold a combined 19 Ml when full, providing between 18 and 24 hours supply. The provision of start/run to waste facilities will improve the ability to prevent water quality deterioration impacting customers and speed the start-up of the site following shutdowns.

The above proposals increase the inherent resilience of the site. Currently no specific proposals are in place to provide alternative supplies from adjacent areas but as part of our overall approach to improving resilience within AMP7 these options are being reviewed and prioritised.

Installation of new un-thickened sludge balance tank (and stirrers) to supply blended sludge and settled backwash to existing thickeners and two new additional thickeners. Provision of new poly dosing unit within existing Ammonium sulphate building. Provision of auto-divert pipework and valves from WRc thickener supernatant to RTW tank pipework if >10NTU.

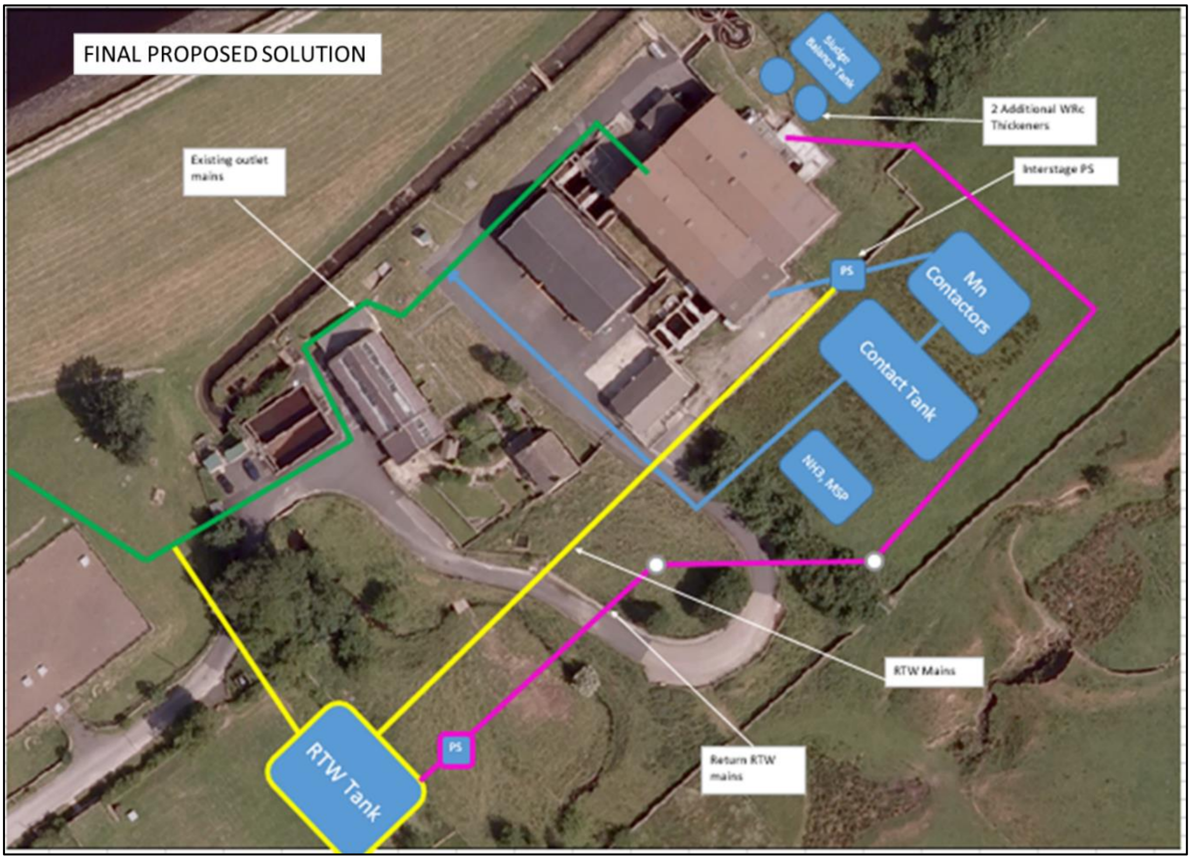

Figure. 36: Embsay WTW: Location of proposed new process units (in blue).

The process diagram below indicates where the new processes interface with the existing and which units are to be de-commissioned.

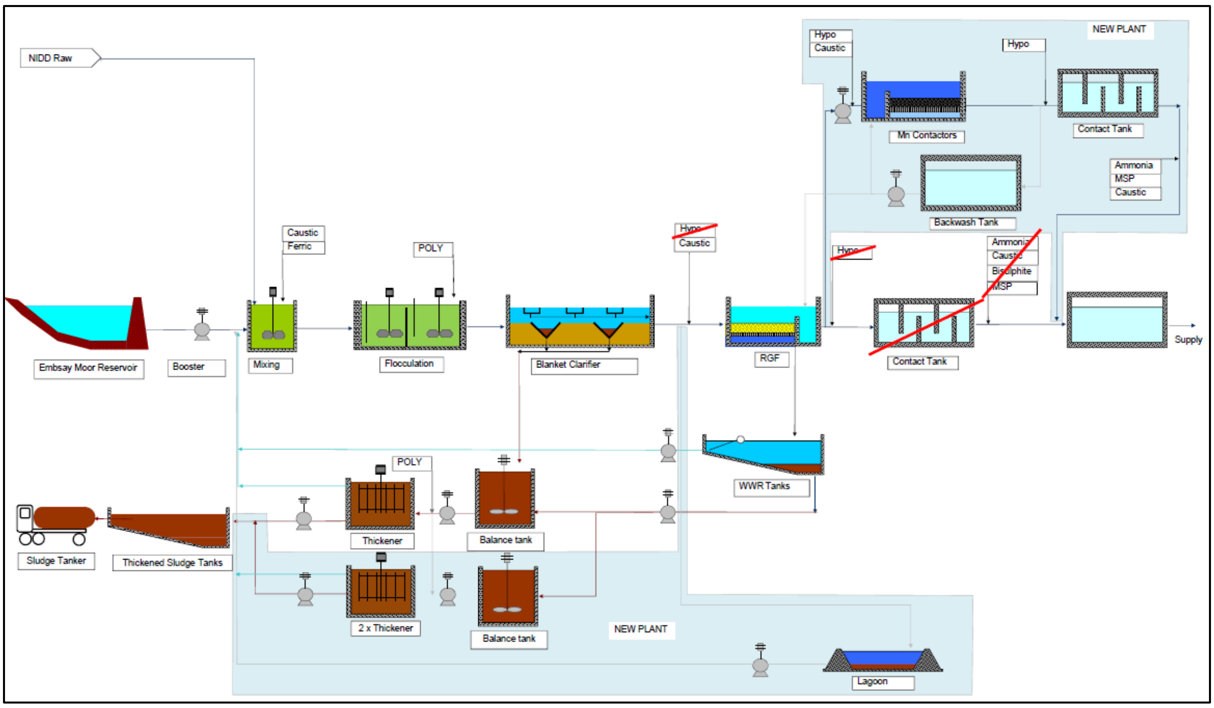

Figure. 37: Proposed solution process schematic.

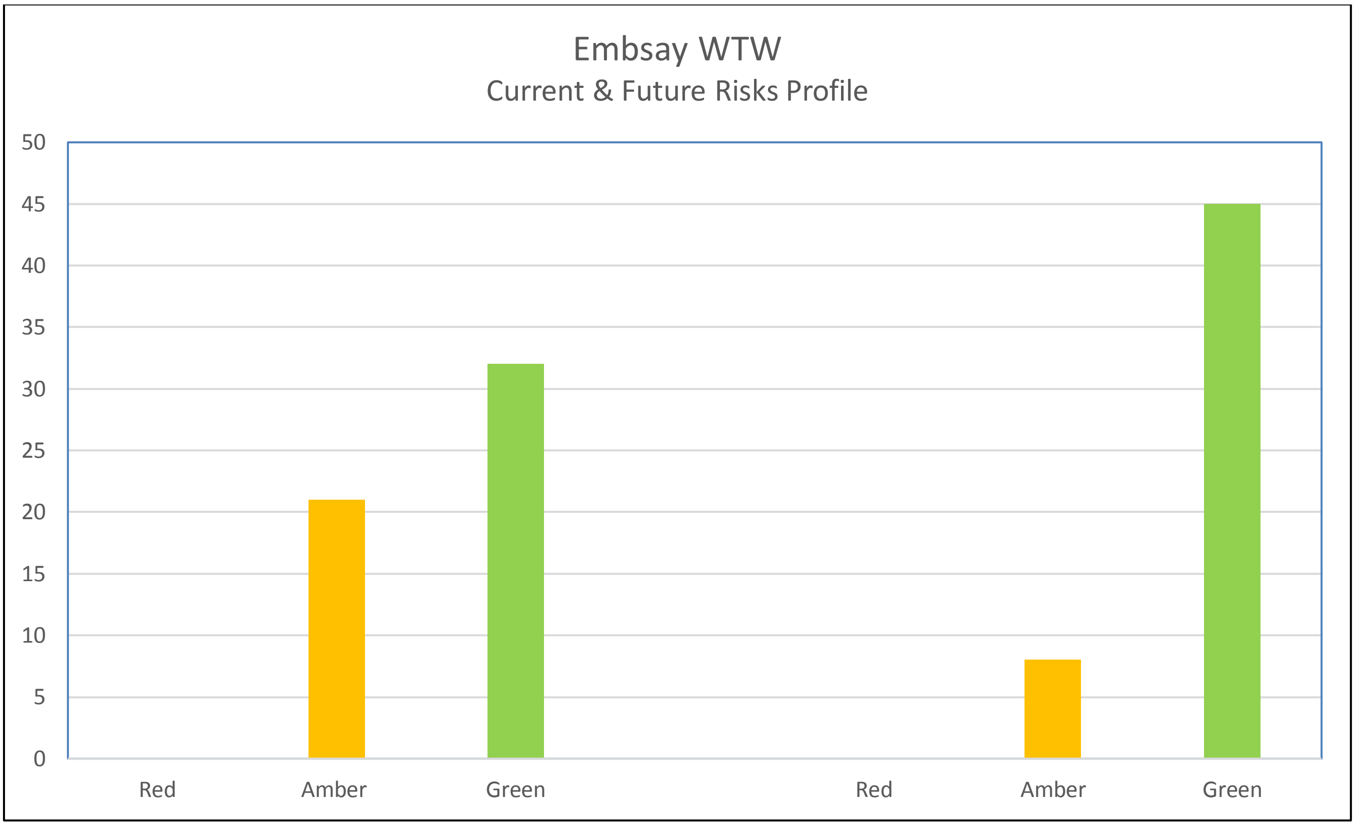

Figure. 38: DWSP change in risk position.

2.5.4 Alternative solution considered

As the primary driver for the scheme is the management of DBPs therefore the logical alternative solution is the installation of ion-exchange for DOC removal. The scheme doesn't include the manganese contactors, but the contact tank and run to waste additions are still to be installed.

	Description	Advantages	Disadvantages	Progress
1	Catchment management	Low capital cost, best long term solution	Long term solution. Included in WINEP for peatland restoration, but timescale for improvements to stabilise DOC likely to be 10-20years; progress alongside all engineered options to secure sustainability of solution and reduce future OPEX/carbon.	No
2	GAC after RGF	Removes DPB precursors.	Requires dechlor/rechlorination if immediately after RGF. Counterintuitive to place	No

			after chlorine dosing stage. THM's already formed. GAC capacity for THM low. Short carbon life of 9 months, high opex.	
3	GAC + Manganese contactor	Removes DPB precursors prior to Chlorine dose. Provides protection against pesticides and T&O	Short carbon life of 9 months, high opex. High land take and Capex.	No
4	PAC (upstream of clarifiers) + Manganese contactors	Dose flexibility Future proofing Provides protection against pesticides and T&O	Needs chlorine dose d/stream of RGF (i.e. Manganese contactors) to be viable. Difficult to operate seasonally Risk to clarifier performance (heavy blankets).	No
5	MIEX Plant	Reduces DPB precursors. Provides future proofing Reduces sludge production and load on thickeners	High operating cost Does not control levels of manganese	Yes
6	Nano filtration for removal of colour	Effective at removing DBP precursors.	Untested in YWS and trialling is not within the current timeframes. High opex cost and risk (membrane life, flux).	No

On balance, the slightly reduced impact on DBP formation of the main proposal is offset by the benefits of lower network risk due to manganese deposition. The catchments which supply Embsay WTW are all subject to current and future activity to reduce the risks of future deterioration; should this prove effective over time; the solution will be sustainable. If catchment deterioration is not able to be reversed then ion—exchange could be required in the future.

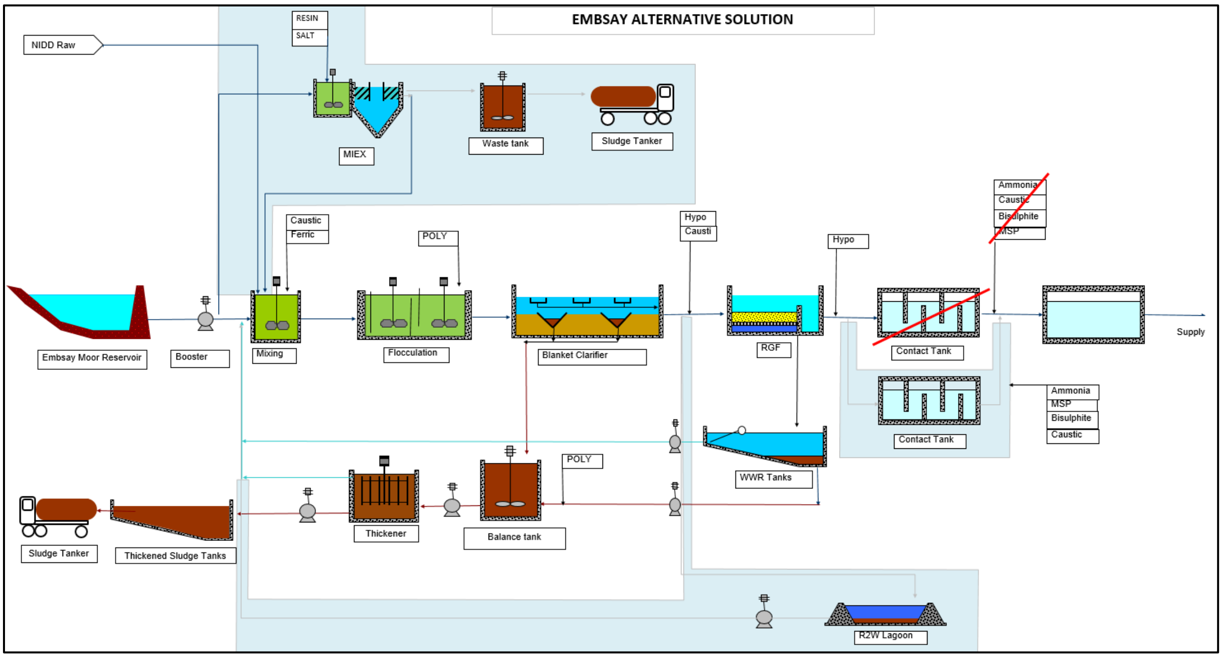

Figure. 39: Alternative solution - process schematic.

2.6 Tophill Low WTW

2.6.1 Overview

Tophill Low WTW is a significant production asset within the Hull (Leven) Water Supply System (WSS) and is capable at full output of supplying around half the City's needs for water. It is mainly supported by the larger groundwater source, Keldgate WTW, but with a major connection to the Yorkshire Water Grid via Raywell CRE – which provides support for resilience purposes. It is a large and complex site, with infrastructure of a range of ages, most latterly having had nitrate removal by ion exchange installed during AMP5.

Table 37: Scheme costs.

Site	Capex (£million)	Opex per annum (£million)
Tophill Low WTW	£ 16.3	£ 0.4

Table 38: Alternative solution costs.

Site	Scheme	Technically Feasible	Risk Addressed	Lowest WLC
Tophill Low - Chosen option	DAF refurb/RGF refurb/interstage ozone/GAC Abs / Contact Tank	Y	Y	N
Tophill Low - Alternative	DAF refurb / PAC contact / RGF refurb / UV	Y	PART	Y
	WLC assessment includes all base maintenance investment required to deliver scheme.			

A significant number of assets are life-expired and pose risks to the reliability of supply in the event of failure. The WTW was designed when raw water quality was less challenging and on the basis that the large storage reservoirs attenuated challenges posed by *Cryptosporidium* and algae abstracted from the river. This is no longer considered the case, in part due to the additional nutrients and oocysts deposited in the reservoirs by wildfowl. Control measures are difficult to put in place to manage this due to the sites' designation as a SSSI which precludes the use of shading or bird exclusion measures.

The consequent increased algal activity has driven the need for increasing dosing of powdered carbon to control MIB & geosmin which compromises the existing treatment process; similarly, the trend in the number of oocysts present in the raw water will take the concentration beyond that which a 2-stage WTW is capable of treating with sufficient reliability to avoid detections in treated water.

We have identified that a more resilient treatment solution is required at Tophill Low WTW to mitigate hazards which are increasing in severity, and over time will result in future risks to drinking water quality or customer acceptability. This comes from risks within DWSPs, and having reviewed data from routine surveillance monitoring, water quality impacting events, and customer contact data,

The key hazards identified are:

Table 39: Key risks to be considered.

Risk	Solution
Drinking Water Acceptability – due to the presence of MIB/Geosmin from algae	Install inter-stage ozone and dedicated GAC contactors
Drinking Water Quality – due to increased levels of *Cryptosporidium* in raw water	Separation of RGF media from hybrid filters – improved wash facilities
Throughput – due to filter clogging by algae and high doses of PAC – not removed by DAF	Reduction in use of PAC due to interstage ozone and GAC contactors to deal with MIB /Geosmin and improved wash facilities

2.6.2 Key Risks to be addressed

Drinking Water Quality Taste and Odour (T&O) - Due to presence of MIB and geosmin in final water

This is caused by presence of algae in raw water. The existing treatment processes are unable to remove the T&O generating compounds without reduction in works output. The empty bed contact time (EBCT) of the GAC layer within the RGFs is insufficient to provide removal. The PAC dosed post pre-ozonation/pre-coagulation has insufficient contact time to effectively remove the taste and odour causing compounds.

The increase in algal numbers is driven by the availability of nutrients from both agricultural and avian sources. The former is included in our catchment management activities in the River Hull, but unlikely to respond quickly, the latter is more difficult as the storage reservoirs fall within a SSSI and steps such as bird exclusion are not appropriate. Computational Fluid Dynamics (CFD) investigations have demonstrated that there would be no benefit from the installation of powered mixing due to the shallow depth of the storage reservoirs. Trials elsewhere have shown limited success with use of barley straw and shading of the storage reservoirs is not feasible due to the significance of the SSSI for waterfowl.

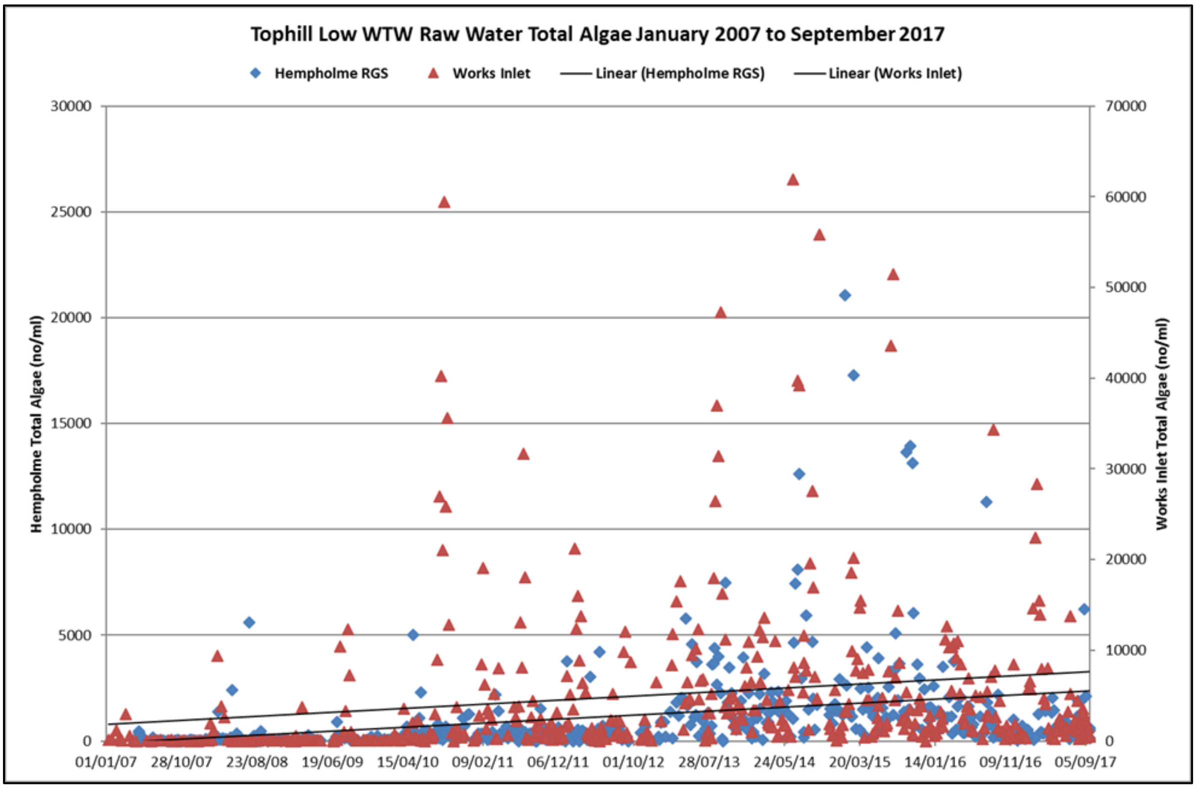

Figure. 40: Tophill Low WTW algae trend.

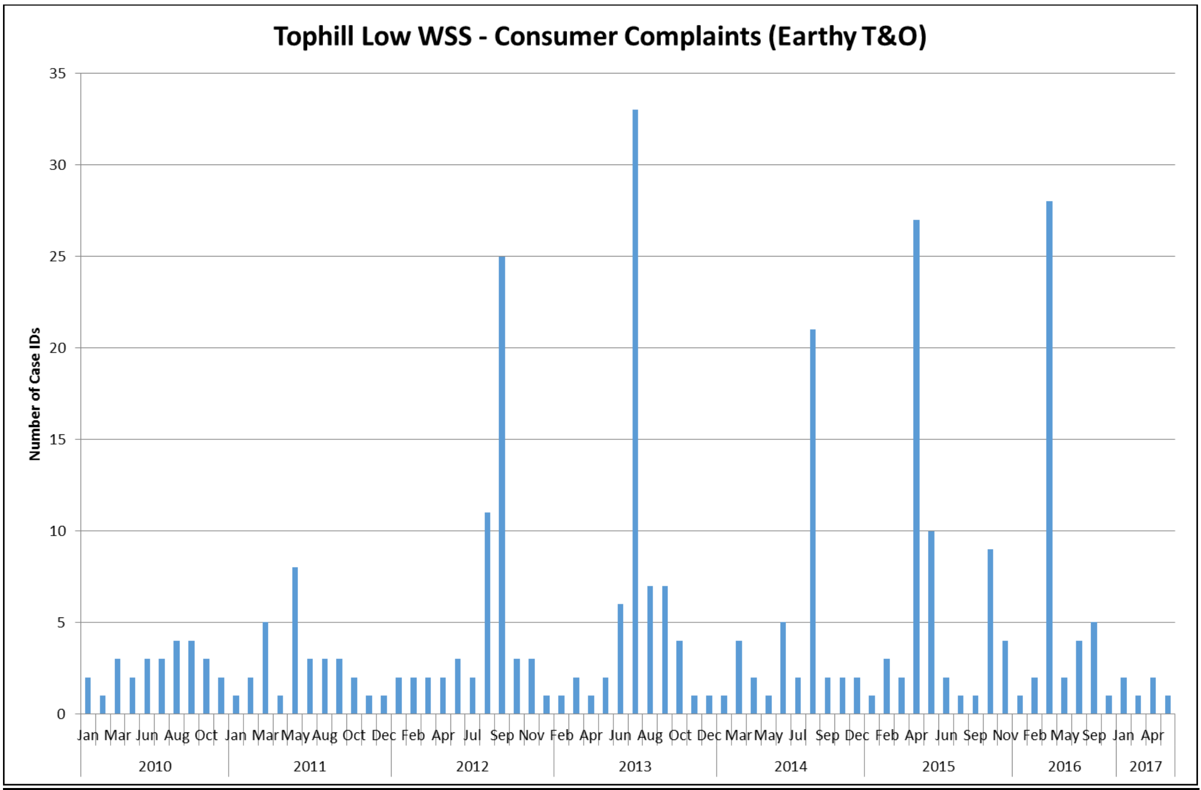

Figure. 41: Taste and odour complaints annual data.

Chart illustrating annual trends in T&O consumer complaints within Tophill Low WSS.

In the chart above, the high peaks in contacts were generally associated with failures of the PAC dosing system, coinciding with high algal loadings, resulting in some cases in notified Events to DWI.

Table 40: T&O consumer complaints.

Earthy T&O Consumer Complaints - Count of Case IDs

Month	2010	2011	2012	2013	2014	2015	2016	2017-part	Grand Total
Jan	2	1	2			1	1	2	9
Feb	1	2	2	1	1	3	2	1	13
Mar	3	5	2	2	4	2			18
Apr		1	2	1	2	27	28	2	63
May	2	8	3	2	1	10	2	1	29
Jun	3	3		6	5	2	4		23
Jul	3		2	33	2				40
Aug	4	3	11	7	21	1			47
Sep	4	3	25	7	2	1	5		47
Oct	3	2	3	4	2	9	1		24
Nov	2	1	3	1		4			11
Dec		1	1	1	2				5

Grand Total	**27**	**30**	**56**	**65**	**42**	**60**	**43**	**6**	**329**

During 2017, due to the introduction of new powdered carbon dosing equipment, contact numbers have been much lower, and the peaks absent, despite continued algal challenge. This approach will provide sustainable, short-term mitigation for the taste and odour issues at the site.

However, the increased PAC dosing has significant impacts on the coagulation and DAF treatment processes, resulting in the need for a significant reduction in flow in order to manage final water turbidity, which is not sustainable in medium to long term.

***Cryptosporidium* – due to increasing numbers of oocysts in the raw water**

As part of the routine review of data within DWSP a significant deterioration in quality of water entering the WTW from raw water storage was noted; this is also seen, but to a lesser extent in the water abstracted from the River Hull. This site was therefore identified as having a potential risk due to the treatment capacity and the increasing raw water risk.

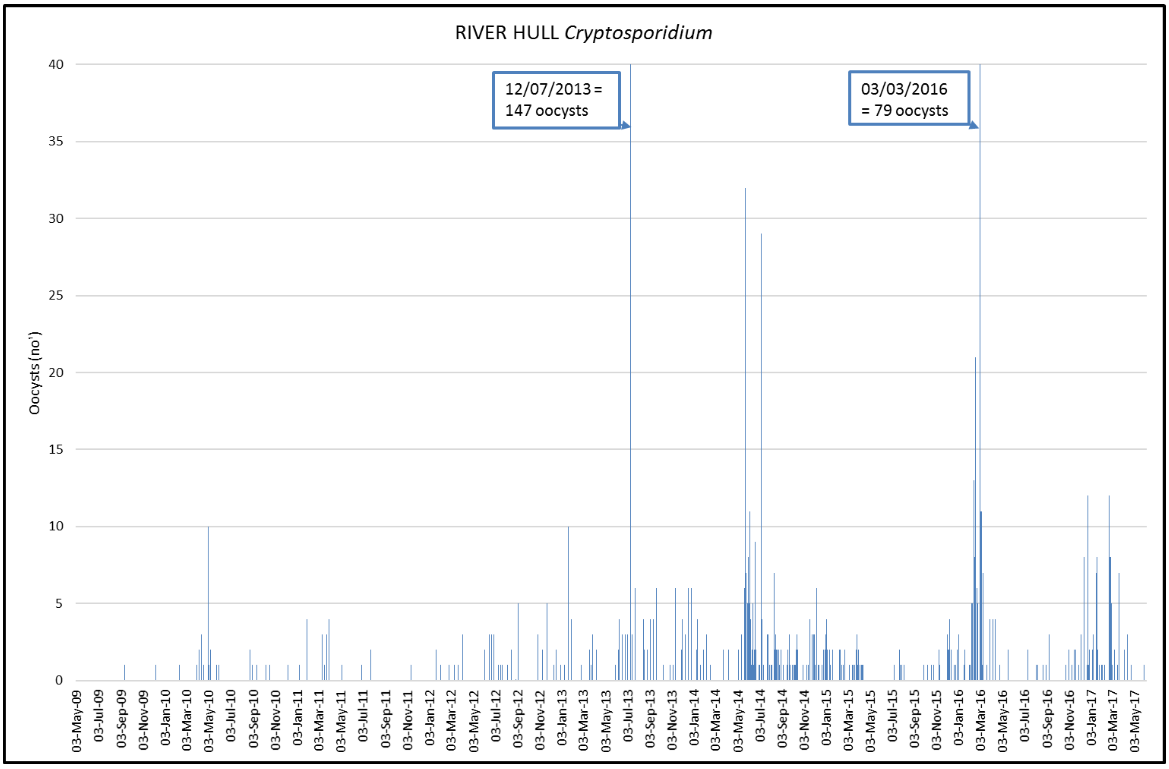

Figure. 42: Crypto results from River Hull.

We have reviewed upstream inputs into the river system and there have been no significant changes, other than that the Combined Sewer Overflows are less likely to operate except under the most extreme weather events.

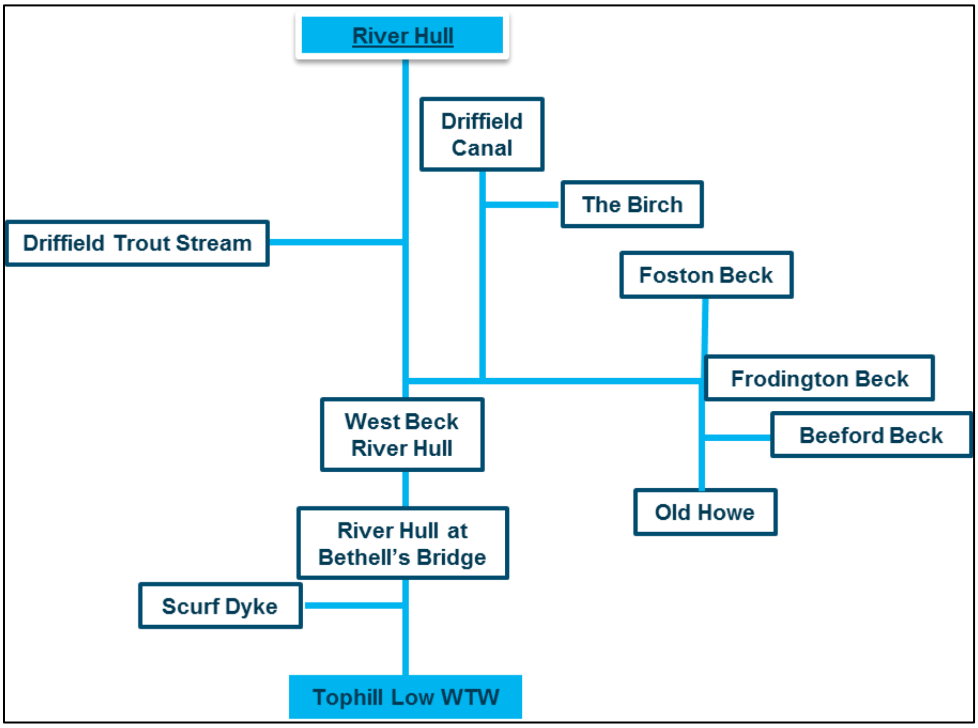

Figure. 43: River Hull system flow diagram.

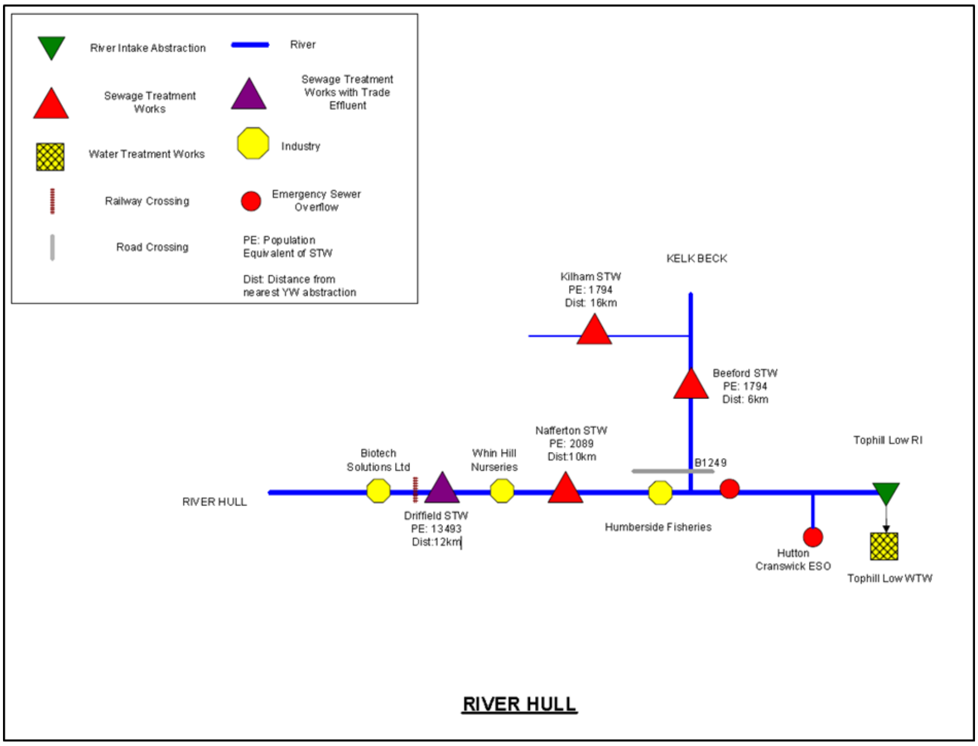

Figure. 44: River Hull water quality risks to abstraction point.

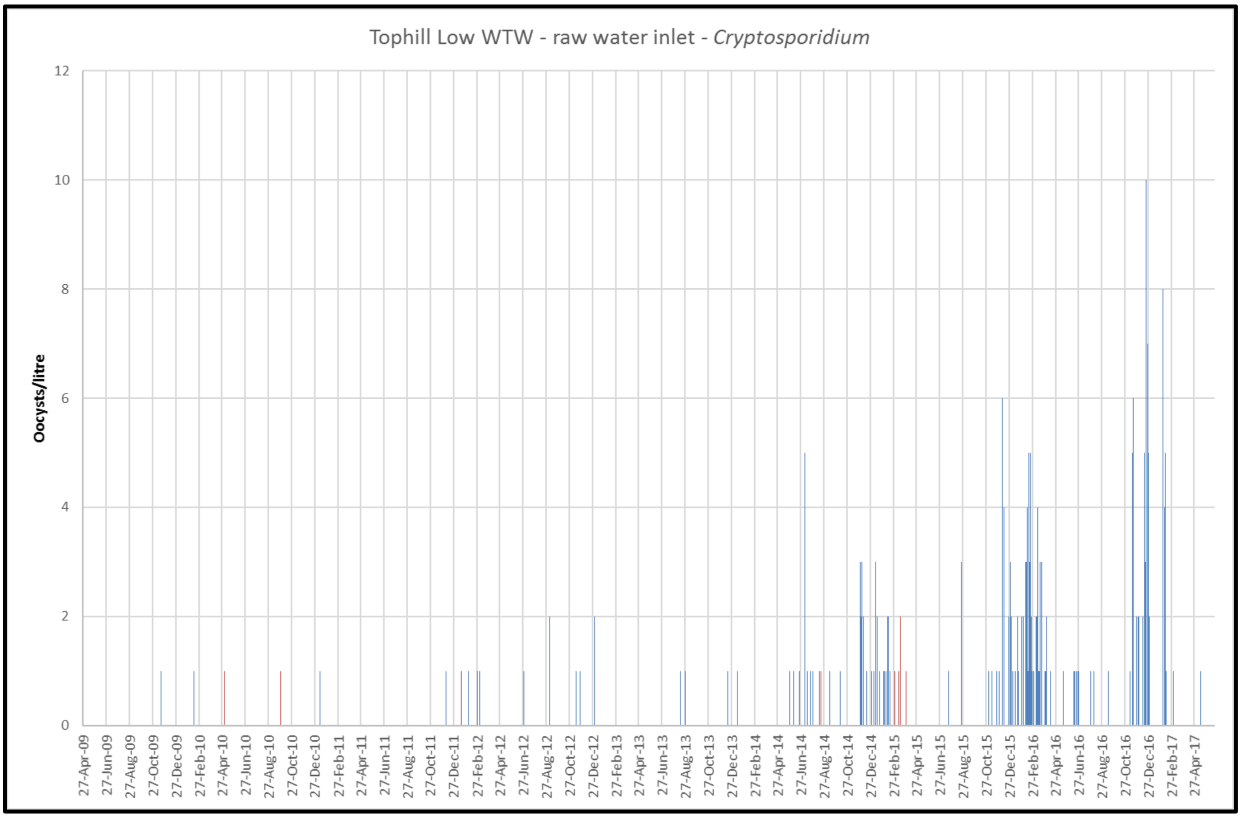

Figure. 45: showing trend in Cryptosporidium oocysts at WTW inlet.

The current WTW only has two solids removal stages and this requires enhancement to allow it to manage the increasing raw water risk effectively into the future.

Current removal capability is compromised by the hybrid filters – part sand filter, part GAC contactor. This provides insufficient removal within the treatment process. The RGF process provides only a single stage filtration of 425mm of 14/25 sand media. This is overlaid with 500mm of 8/18 GAC media to provide pesticide and taste and odour adsorption. This level of filtration does not provide an acceptable level of log removal for the filtration stage of a surface water treatment works.

Loss of WTW Output - due to RGF blinding caused by algae

During high algae periods the RGFs blind due to algae passing forward from the clarification process. This leads to loss of throughput and leads to a loss of resilience within the water supply system.

2.6.3 Investment to improve overall site resilience

Whilst resolving the key risks to treated water quality identified above we intend to resolve the following other risks:

- Loss of WTW Output - due to RGF backwashing availability caused by dirty wash water (DWW) constraints; filter throughput has to be reduced to maintain filtrate quality. The minimum available RGF runtime is limited to 28hrs. This is due to the DWW capacity and performance which requires four hrs to deal with a single RGF backwash. During high algae periods the RGFs cannot be washed when required, for instance, at less than a 24-hour frequency. Plant flows have to be reduced to extend the filter runtimes to meet the 28-hour limitation. Also, there are restrictions in RGF backwash availability due to constraints in the clean backwash water supply. This is limited due to the size of the backwash clean water tank and the tank recharge flow available and would not support the RGF washing frequencies required during high algae periods.

- High levels of Algae in the DWW sludge extend sludge filter press runtimes creating a backlog in the DWW sludge holding system. To maintain WTW throughput requires the DWW sludge to be tankered off site prior to dewatering.
- Bacteriological & *Cryptosporidium* risk - due to the risk of ingress into the clean water tank caused by fluvial or pluvial flooding. The CWT also acts as the disinfection contact tank, the tank has known structural shortfalls which could permit the ingress of rainwater or flood water were it not for regular inspection and mitigation. Ultimately the tank will need to be replaced; the first step in this journey is to provide a dedicated contact tank as proposed.
- The site doesn't have a dedicated asset standard disinfection contact tank as preferred for a river fed works, disinfection is effected across the Clean Water Tank which is not in line with the current asset standard.
- Water Availability - Due to failure of RGF lining caused by blistering of epoxy lining
- The RGFs are coated with an epoxy coating to protect against concrete degradation. The coating is showing signs of failure with blistering. If the coating fails it could block the RGF nozzles and pass forward into the final water.
- Resilience - WSS risk - Hull distribution requires Tophill to do 65ml/d to supply if Keldgate fails. - In the event of total failure at Keldgate WTW, to meet average demand in Hull (120-130Ml/d) Tophill is required to output 65 Ml/d with Grid import maximised at 75 Ml/d to Raywell CRE.

The existing site is congested and complex, having been extended over the years, and with the added constraint of the River Hull to one side of the site, a SSSI to another, neighbouring premises and existing process units. The most recent upgrade, during AMP5, was the installation of an ion-exchange process to remove nitrate.

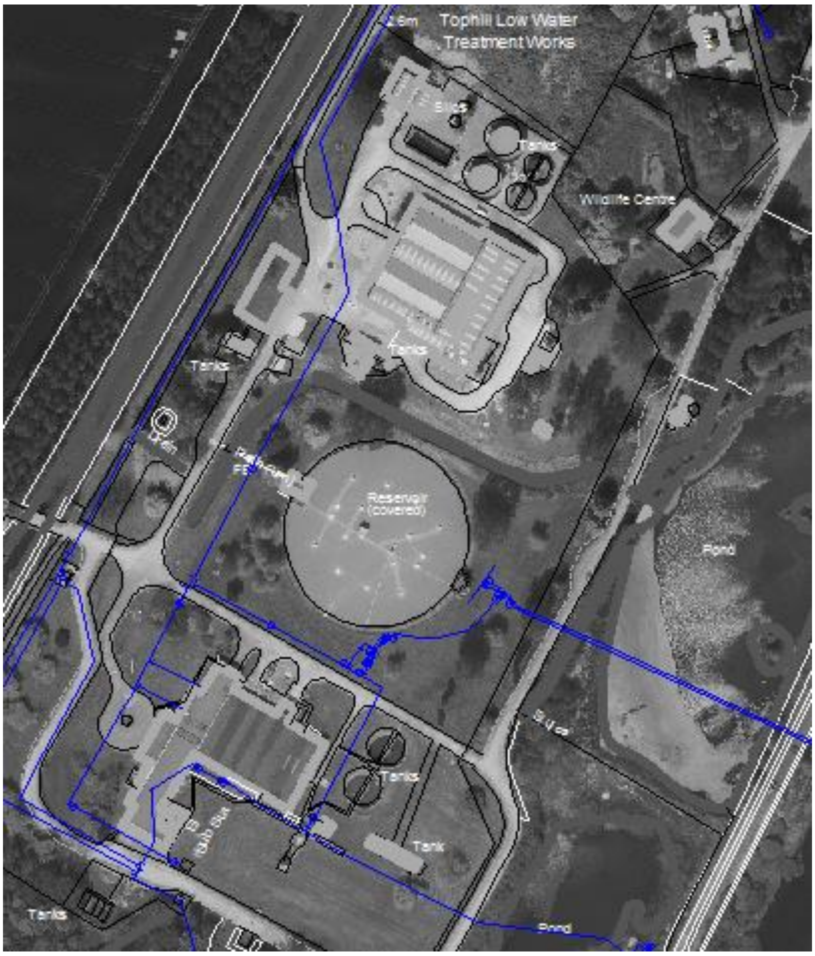

Figure. 46: Existing site layout.

2.6.4 Proposed solutions

The solution proposed is targeted at resolution of the risks as described above. It includes the following key enhancements and additions to the existing processes. The proposed locations for additional or re-located process units are shown on figure 48 below.

Drinking Water Quality contacts - Taste and Odour

Providing a solution to the presence of MIB and geosmin in the final water caused by presence of algae in raw water. The existing treatment processes are unable to remove the T&O generating compounds without compromising other aspects of treatment due to PAC solids and consequent reduction in works output. The EBCT of the GAC layer within the RGFs is insufficient to provide complete removal.

The scheme will provide inter-stage pumping after the current rapid gravity filters to a new ozone dosing and contact stage. After ozone contact the water will pass to a block of new GAC absorbers designed for the removal of T&O causing compounds, enhanced pesticide removal and to permit reduction/ceasing of PAC dosing.

Cryptosporidium

Following completion of the new GAC filter block the scheme proposes to refurbish the existing RGF hybrid filters and convert them to asset standard sand/anthracite RGFs with enhanced particle removal capability. Once the scheme is completed the site will have the desired 4-log removal capability for oocysts. In addition, the new wash-water recovery system (lamella separators) – will enable the new filters to allow 24 hour RGF wash cycles when algal activity is high.

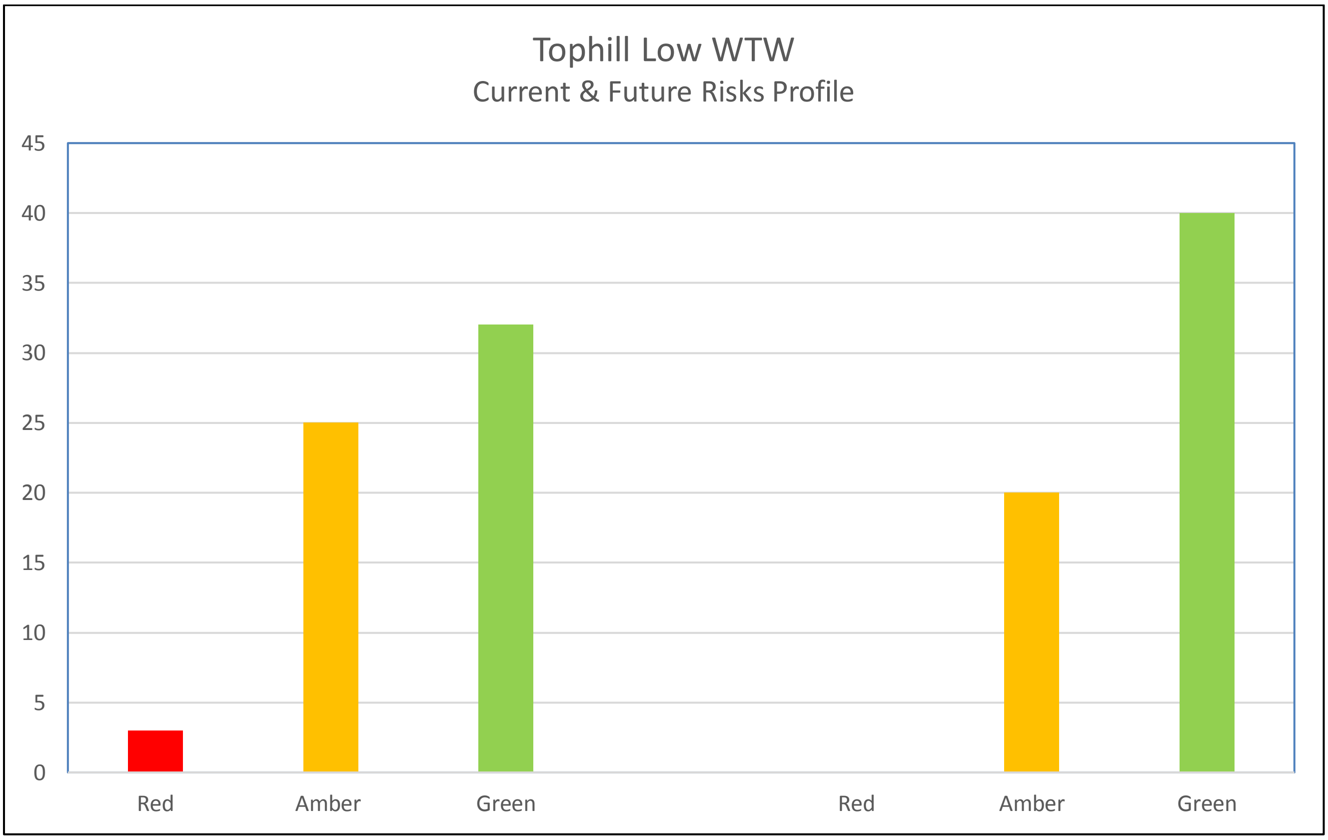

Figure. 47: DWSP change in risk position.

Site Resilience

As part of the long-term plan for the site, and specifically to allow future flexibility for remediation or replacement of the existing clear water tank a new contact tank will be built to ensure effective disinfection.

Figure. 48: Proposed location of new or refurbished processes

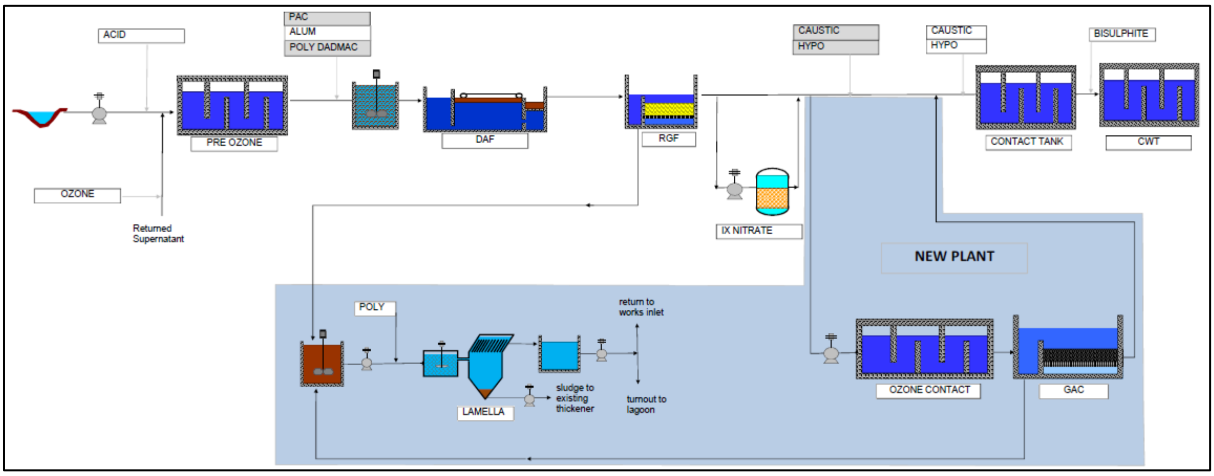

Figure. 49: Process schematic: proposed solution.

Details of mid to long term control measures

Catchment

The River Hull catchment is within a Natural England Countryside Stewardship high priority area for water quality including phosphate, nitrate and pesticides. Within those priority areas incentives are offered to farmers to adopt agricultural practices which will safeguard water quality and meet the Water Framework Directive. The incentives can help enable farmers to improve farm infrastructure and deploy in-field mitigations against nutrients and *Cryptosporidium* losses to the watercourse.

Table 41: Catchments in WINEP.

Driver Description	WINEPID	Function	RBD	Area	Water Company	Unique ID	Scheme Name	Waterbody	Waterbody ID	Water Body Type(s)	WFD Catchment	Driver Code
Investigation / Options appraisal for Flow regime	YOR00010	WR	Humber	Yorkshire	Yorkshire Water Service Ltd	7YW100075	BOREHOLES - CHALK - KILHAM	Gypsey Race from Source to North Sea	GB104026072790	River	Gypsey Race	WFD_INV_WRFlow
Drinking Water Protected Areas	YOR00196	WQ	Humber	Yorkshire	Yorkshire Water Service Ltd	7YW200140	CSF officers Yorkshire wide all parameters	Catchment Scale	Catchment Scale	Catchment Scale	Catchment Scale	DrWPA_ND

WWTW - The current technical limit for phosphorus removal at the WWTW is 0.5 mg/l annual average. There is currently a national trial to understand whether the limit could be further reduced to 0.1 mg/l annual average from 2020. The success of this trial can then start to initiate changes to be made to all WWTWs and therefore reduce the nutrient loading from the WWTWs.

Options the company has considered, for example catchment management

The River Hull catchment has been included in the WINEP to fund catchment officers. The action plan is to increase the level of engagement on water quality and allied matters within the catchment and to utilise learning from our activities in other catchments.

2.6.5 Alternative Solutions considered

The potential alternatives are as follows and include options reviewed in the pre-workshop and from this review.

Table 42: Alternative solutions.

	Description	Advantages	Disadvantages	Progress
1	Direct river abstraction bypassing bankside reservoirs. Pre-sedimentation tank/lamella for gross solids settlement. UV disinfection (for Crypto) RGF upgrade.	Eliminates the algae T&O issues if primarily reservoir grown. Effective Cryptosporidium removal with UV.	Removal of bankside storage increases Crypto risk – hence need for UV disinfection. Loss of bankside storage capacity (pollution protection and poor river water Q.	No
2	Cover Reservoirs with Solar panels to block out light to algae. RGF upgrade	Generates renewable energy. Eliminates algae growth.		No
3	Control algae in reservoir (barley straw, ultrasonics). To reduce algae to manageable levels by existing DAF and PAC.	Treatment at source.	High opex costs for barley straw. Ultrasonics can be very specific/may allow other algae to bloom.	No
4	Catchment solution		Longer term strategy, not viable in short term.	No
5	Raw water source optimisation/abstraction utilising West Beck		Uncertainty on abstraction capacity/quality of West Beck. Requires time for review.	No

6	Install dedicated PAC contact tank to increase contact time and improve efficiency of PAC. UV treatment Contact tank Washwater recovery upgrade	Effective Cryptosporidium removal with UV	Uncertainty if it can be effective as GAC+ Ozone (main option)	Yes

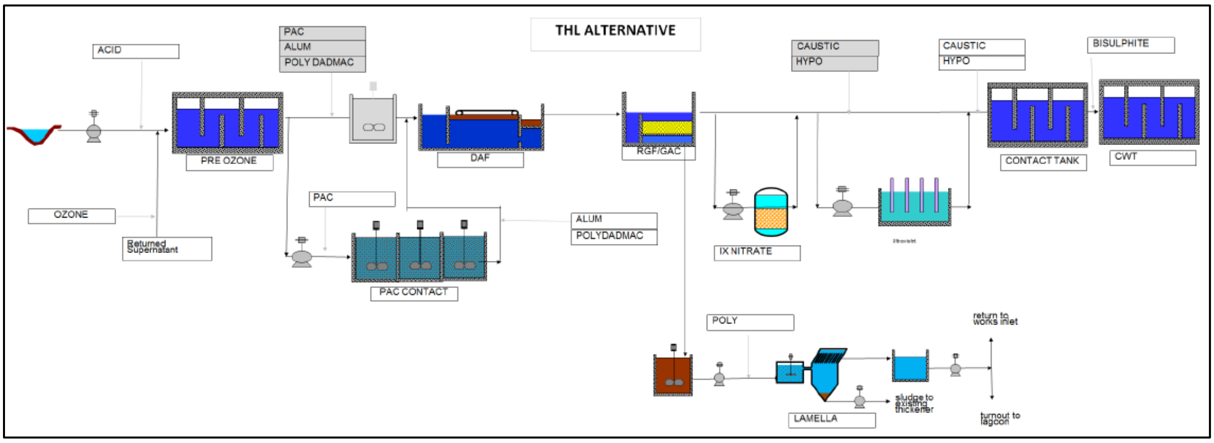

Figure. 50: Process schematic – Alternative solution.

2.7 Lead

2.7.1 Our strategy toward removing lead risk

Table 43: Scheme costs.

Site	Capex (£million)	Opex per annum (£million)
Lead Pipe Replacement	£ 15.0	£ 0.0

Table 44: Lead scheme costs.

Lead Pipe Removal Schemes	Capex (£million)
Helping Hands	1.2
Education Establishments	0.9
Replace on sample failure	0.7
Customer requested	2.9
Hotspot DMAs	7.8
Lead Trials	1.5
Total	15.0

2.7.2 Previous activity on lead risk reduction

Over the past few AMP periods we have made significant progress in managing the risk from lead, investing significant sums of its' customers charges into risk reduction activities. To date, much of our focus has been on delivering a successful plumbosolvency control programme, which now covers almost 100% of distributed water. We base our approach on four key principles: -

- The reduction in background organics in distributed water
- The identification and adoption of optimal phosphate doses
- The maintenance of appropriate distributed water pH
- The undertaking of research and development to further our understanding and approach

Throughout AMP3 and AMP4 we minimised the need for investment through optimisation of orthophosphate dosing and pH correction; this was effective in achieving the 25µg/l standard. The addition of phosphate to around 98% of supplies in Yorkshire has also moved us a significant way towards achieving the 10µg/l standard. However, it was recognised that as a result of the change in standard that compliance would deteriorate in 2014 onwards, despite significant efforts to achieve a real improvement in consumer exposure to lead.

During AMP4, we undertook a small-scale trial which investigated the feasibility of replacing a more significant proportion of the lead, the willingness of customers to permit this activity, and the cost of doing so. This project demonstrated that there were significant benefits in lead exposure reduction accruing from the replacement of more significant proportions of the service; however, cost and customer access proved to be significant barriers to this approach. We combined this with a programme of lead communication pipe replacement or lining which has demonstrated some improvement in compliance, but is a long way short of providing a complete solution

The change in standard during AMP5 meant that we could not guarantee meeting the lowered PCV through optimised dosing and operational strategies such as 'free & matching' Lead pipe replacement. This resulted in a lead communication pipe replacement programme that contained three outputs. Two schemes proactively addressed Lead communication pipe replacement in the Leeds area and one scheme targeted high risk 'hotspot' DMAs, based on the data from an 18-month period of enhanced monitoring. We also replaced the communication pipes of over 1200 vulnerable customers.

The final element of our AMP6 approach to lead was a trial in partnership with Rotherham MBC. The objective was to understand the benefits and challenges of lining 1,000 lead service pipes in the East Herringthorpe area of Rotherham. We submitted a report to the DWI in September 2017 which explained the benefits and challenges of this trial, and presented the findings to an Industry workshop.

Our activity for the Rotherham service pipe lining trial allowed us to contribute towards the development of the "Whirlwind" application technique, an in-situ lining product which gave the Industry choices, alongside other mitigation techniques, in facilitating reduction of lead risk.

2.7.3Sources of lead risk

The most significant cause of lead non-compliance is the presence of lead pipework between our water mains and the point of use. The greatest proportion of lead piping is generally present in the customer's privately-owned supply pipe and internal plumbing. There are circumstances where other fittings may contribute to the risk but these are generally of much lesser significance.

Lead services and plumbing can be found to varying degrees across most of the country; previous work estimated there to be around a million lead services in the Yorkshire Region, typically providing supplies to older properties in the Yorkshire conurbations.

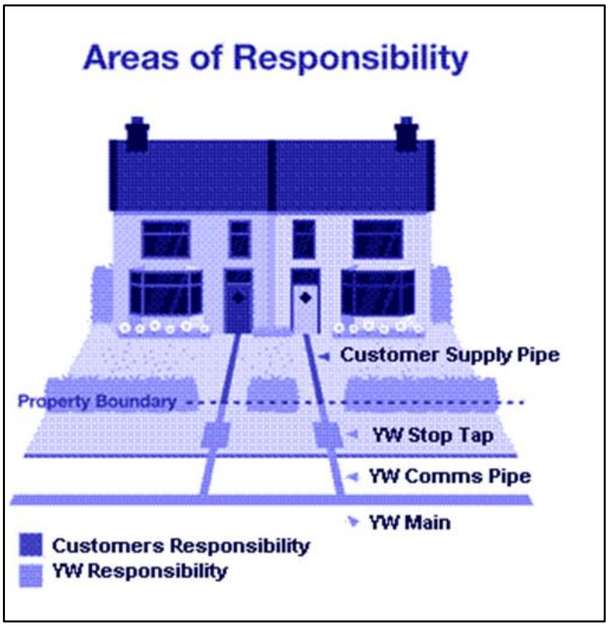

Figure. 51: Areas of responsibility.

With the water company having responsibility for the communication pipe and the property owner having responsibility for the supply pipe, this has generally meant that lead pipe replacement programmes by the water company has not been able to maximise the water quality benefit to the customer. Figure 51 shows the boundary between the company and privately-owned assets.

One of the key drivers for undertaking the lining trial with Rotherham MBC was to explore the potential benefits (to the customer) of rehabilitating the entire service pipe and hence contribute to the debate regarding the ownership of the supply pipe. In addition, it was intended to explore the challenges, both physical and property related, which come with working on the customer premises.

2.7.4 Existing Controls in Treatment and Supply

The principle control mechanism to minimise the potential for Lead pick up is the continuous addition of phosphate, effective DOC removal, and pH optimisation and control at each supplying WTW. Optimisation is then continued by review of sample data from lead rigs at WTW outlets and the maintenance of optimal conditions is verified by routine assessment of lead concentrations within each WSZ.

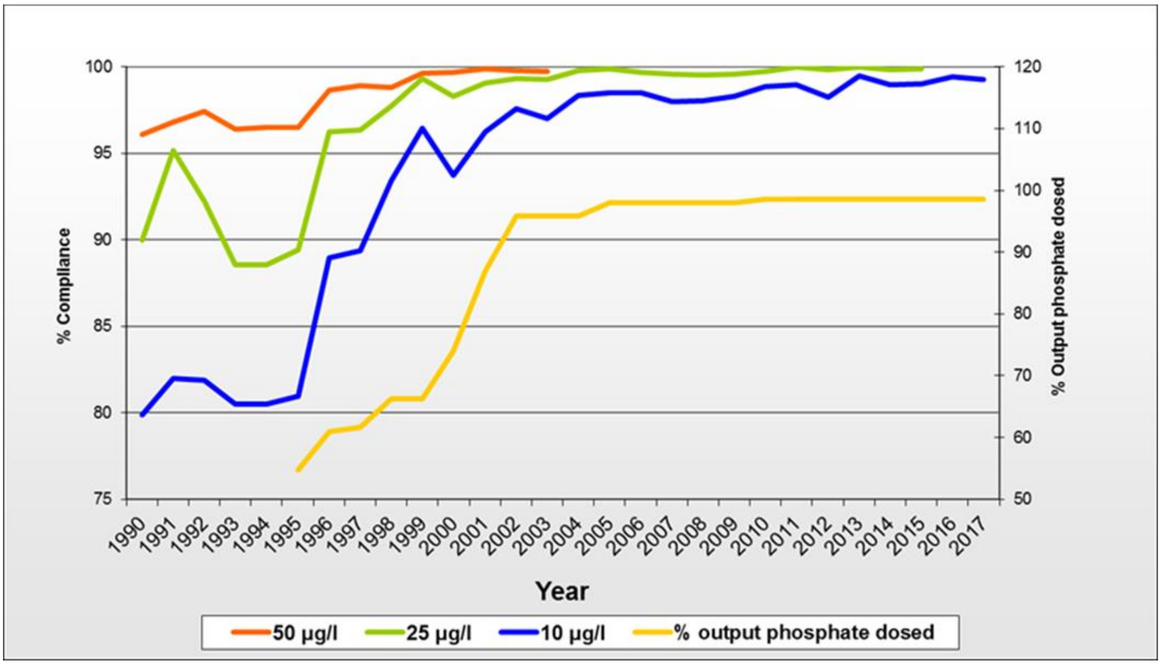

Figure. 52: Lead Compliance and Phosphate Dosing.

Figure 52 shows an initial improvement from 2000 onwards. This is a result of additional Plumbosolvency control and then general improvement due to optimising P dose and pH. In 2012 there was a slight decline due to poor raw water quality. Phosphate levels leaving WTWs and at customer's taps are routinely monitored. The performance and effectiveness of these controls is regularly reviewed in order to ensure it is fully optimised at all times.

Figure 53 shows the lead sample failure rate from 2010 onwards and despite some small 'spikes' in results, the general trend is an improvement in the sample failure rate.

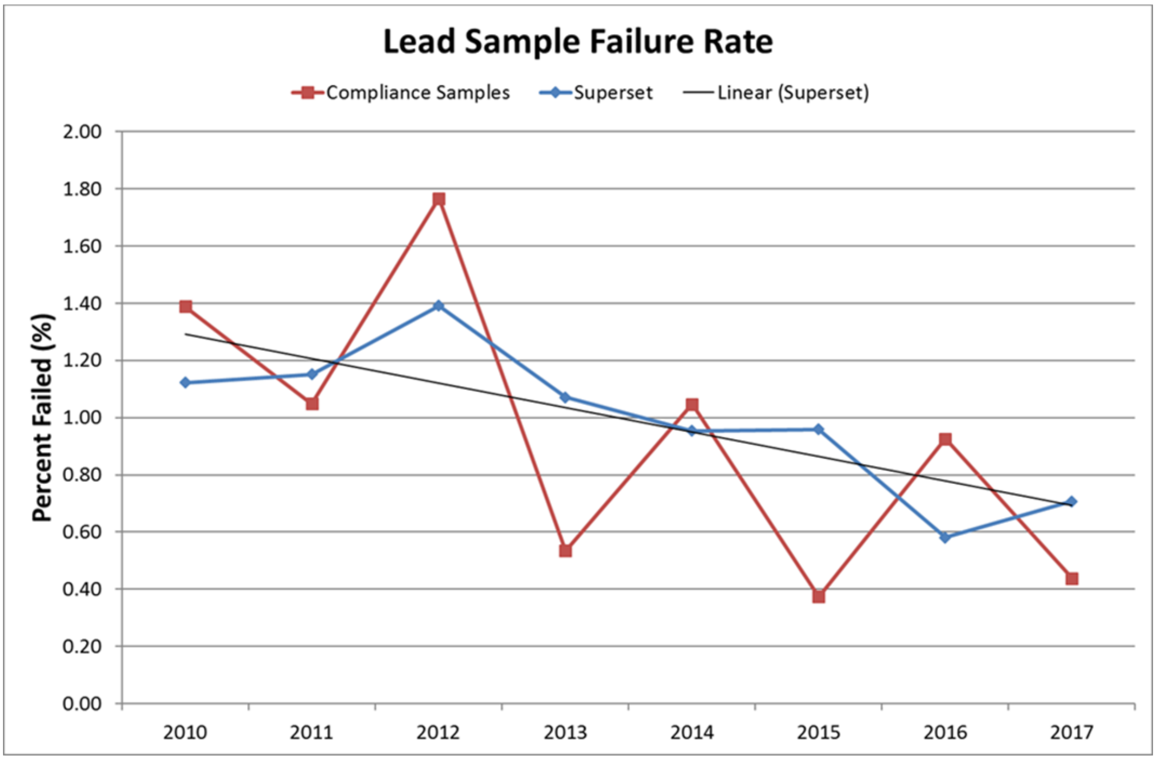

Figure. 53: Lead Sample Failure Rate.

2.7.5 Proposals for action during AMP7

During AMP5 we commissioned MWH to undertake an investigation that would enable the development and maintenance of a communication pipe inventory. Part of the study enabled us to have a greater understanding of the likely service pipe material. This has meant we can cross reference the communication pipe inventory with the 5154 vulnerable customers. This has given us a list of 1,029 with a high likelihood of a Lead communication pipe. This is in addition to the 1222 that were identified as part of the PR14 process of having a lead communication pipe. All these properties will be surveyed to determine the actual nature of the communication pipe. If the communication pipe is confirmed as Lead, it will be replaced / rehabilitated.

The MWH service pipe study assessed domestic premises to understand the likely material type of the communication pipe, and also assessed other types of buildings. This give us the opportunity to look in further detail at areas that would provide the highest risk in terms of lead exposure. As children are at greatest risk, we have assessed the schools that have been identified in the study. Where a school has a high chance of having a lead communication pipe, and provided that we get agreement from the school, we will aim to renew / rehabilitate the lead pipe. Based upon the analysis carried out we expect there to be 205 schools in the Yorkshire region with a high possibility of having a lead communication pipe.

2.7.6 Identification of lead risk

Throughout AMP4, AMP5 and AMP6 additional samples have been collected to determine the effectiveness of plumbosolvency optimisation at a rate of five times the regulatory frequency. The samples are taken from additional customer properties randomly selected and taken in the same manner as regulatory purpose samples. This enhanced sampling frequency will continue throughout the AMP7 period.

The outputs from the greatly increased spatial coverage given by the enhanced dataset allows more meaningful analysis at DMA level than would be the case at the regulated frequency. This has enabled us to better understand the risk of all DMAs and their performance against the new Lead standard. If a DMA has been subject to more than one sample per year exceeding 4µg/l within a 3-year period (2013, 2014 and 2015), it is proposed that a strategic lead investigation programme be adopted.

We consider that the current rate of failure is likely to continue for the foreseeable future. This is on the basis that the number of communication pipes replaced only represents a small proportion of those that exist, and that generally a more substantial length of lead is contained within lead services.

We have had five notified events for Lead in AMP6. These are shown below

Table 45: Lead notified events in AMP6.

year	month	YW Ref	DWI Ref	Description	Date	BU	Re-Class to post 2009 version
2015	7	HAR 15	2015 - 5116	Cavendish Street, Harrogate - Lead Fail - Do Not Drink	14/07/2015	Distribution	2. Minor
2015	8	HOY 15	2015 - 5158	Hoyle Hill Lane, Thurlstone - Lead Fail - Do Not Drink	05/08/2015	Distribution	2. Minor
2015	9	HEN 15	2015 - 5221	Henshaw Avenue, Yeadon - Lead Fail - Do Not Drink	08/09/2015	Distribution	2. Minor
2016	6	DEW - 16	2016 - 5569	Wakefield Road, Dewsbury - Do Not Drink	17/06/2016	Distribution	2. Minor
2016	6	BRA / 2 - 16	2016 - 5570	Hillsaide Terrace, Bradford - Do Not Drink	19/06/2016	Distribution	2. Minor

2.7.7 Regional DMA hotspot scheme

We have used the same methodology to identify potential lead hotspots as a means of targeting our activities where they can be most effective. Again, we have used a criterion of 4µg/l to derive this measure of risk (against the standard of 10µg/l). The "hotspot" approach means that this element of our lead communication pipe replacement scheme will cover DMAs in several different Water Supply Systems (WSS). Figure 54 shows the location of the DMAs across the region.

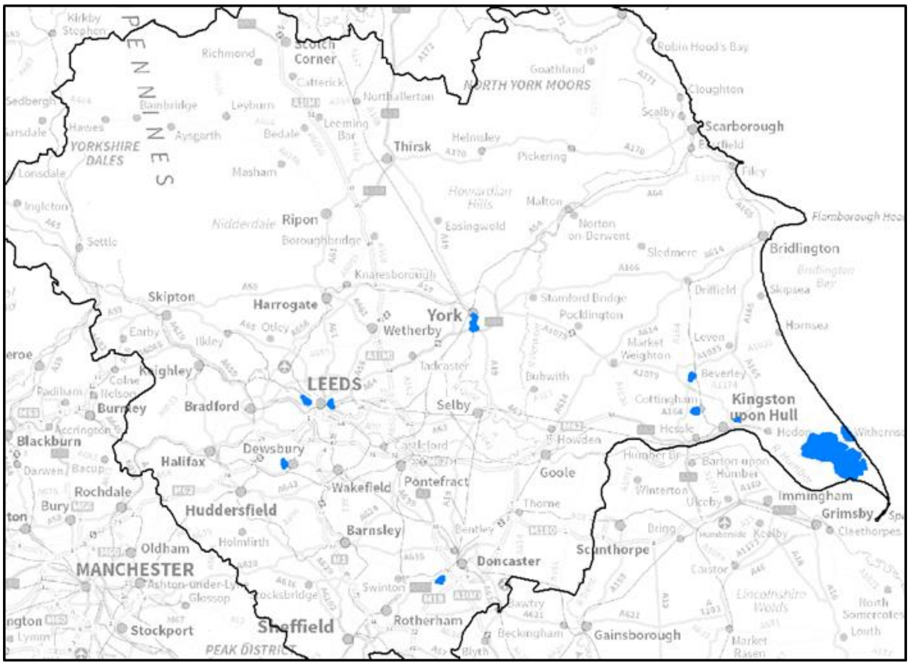

Figure. 54: Hot Spot DMA Locations.

For the 'hot spot' approach, **Error! Reference source not found.**48 shows the WTW supplying the DMA and confirmation that MSP dosing is carried out at the respective WTW.

Table 46: Hot Spot DMAs and MSP Dosing.

DMA Ref	DMA Name	WSS	WSZ	Supplying WTW	MSP dosing?
G086	AVIARY ROAD DMA	Leeds Low Level	Bramhope/Holebeck	Headingley	Y
F772	CENTRAL AVENUE DMA	Hull	Beverley	Keldgate	Y
C068	CHURCH LANE DMA	Dewsbury	Dewsbury	Holmbridge	Y
G021	EBOR DMA	Leeds Low Level	Leeds LL Cross Green	Headingley	Y
D526	NORTH FEATHERSTN DMA	Clifton	Doncaster Rural	Nutwell	Y
Y044	NUNNERY LN YORK DMA	York	York West	Acomb	Y
F651	PATRINGTON DMA	Bilton	Holderness	Tophill Low	Y
G120	PONTEFRACT LANE DMA	Leeds Low Level	Leeds LL Cross Green	Headingley	Y
F789	TELFORD DMA	Hull	Holderness	Tophill Low	Y
F654	THE PARKWAY DMA	Hull	Beverley	Keldgate	Y
F619	WITHERNSEA DMA	Bilton	Holderness	Tophill Low	Y

The anticipated number of properties requiring lead renewal / rehabilitation at DMA level are based upon the experience and results carried out at DMA level as part of the 'hot spot' scheme in AMP6. On average, throughout the 20 DMAs that we carried out lead renewal / rehabilitation, 44% of all properties contained a lead pipe.

Vulnerable Customers

The intention is to continue to work with our vulnerable customers in a targeted rehabilitation or replacement of lead services. As mentioned, in AMP6 we replaced over 1,200 service pipes of vulnerable customers. This was based upon criteria identified within our 'Helping Hands' database (now known as 'Priority Services') that have a high probability of a lead pipe connecting their supply. We are continually updating the 'Priority Services' database and this has resulted in further properties being identified where a vulnerable customer may live. Where it is identified that these properties may have a lead service, our intention is to replace / rehabilitate the communication pipe. Where the customer approves, and it is possible to do so from a practical perspective, we will aim to also replace / rehabilitate their supply pipe as well. Based upon the data we have, we expect to renew / rehabilitate approximately 5,000 communication pipes (and where possible, supply pipes as well).

Centres of Education in Yorkshire

We acknowledge that children are particularly vulnerable to the effects of lead, and that even relatively low levels of exposure can cause serious damage. In the Yorkshire region, in order to reduce a childs' potential exposure to lead we plan a programme of renewal / rehabilitation of lead communication pipes, and where agreed, supply pipes, that supply our schools and nurseries. We understand the potential challenges that this work may bring, such as safeguarding, and anticipate that this activity will mainly need to take place over holiday periods when schools are closed. Our recently appointed Safeguarding Officer will provide expertise associated with this new challenge,

Replacement on exceedance of the 10µg/l standard

Under Regulation 17(9), we are required to replace our pipes and fittings where a sample has exceeded the 10µg/l standard.

Lead pipe replacement – customer request scheme

In line with the our 'Lead Replacement Policy', we fund the "free and matching" replacement of the lead communication pipes at the request of the customers who have replaced all sections of lead in their supply pipe or internal plumbing system. Requests are generally received from individual customers, landlords, housing associations and local authorities undertaking large scale property refurbishment programmes. Again, due to the random nature of the requests, it will not be specific WSSs or DMAs that we are working in, this will be a region wide programme.

2.7.8 Risk Characterisation within DWSPs

Our risk assessment is based on the percentage of failures within a WSZ in the last 3 years. The following assumption, shown in figure 49 has been made to score the risk associated with a certain failure rate.

		Pre Risk		Post Risk	
		P	S	P	S
% sample failures	>6%	5	5	4	5
	3-6%	4	4	3	4
	1-3%	3	4	2	4
	<1%	3	3	2	3

Figure. 55: Assessment of Lead risks within the DWSP Methodology (based on sample failures at WSZ-level).

Control Measures Required

Short Term

A review of pH & phosphate levels, plumbosolvency control data, and WTW performance with respect to organics, are carried out on a routine and regular basis.

We carry out regular onsite tests at each WTW, and an additional number of operational lead samples over and above the regulatory sampling programme.

Medium Term

We will continue to undertake lead pipe replacement or lining to complete the programmes of work identified and in response to significant failures of the standard.

In the short and medium-term customer advice will highlight the potential risks posed by lead services and the requirement to flush after periods of low use. The images below show some of the information that we provide to our customers.

Refurbishing our old lead pipes

Thousands of homes in Yorkshire will soon see their lead water supply pipes refurbished to comply with European regulations.

Between now and March 2017 £13 million will be invested in the following areas; Beverley, Bradford, Doncaster, Hull, Knaresborough, Leeds, Malton, Northallerton, Rotherham, Sheffield, Wakefield and York.

The work is required to comply with new standards that are being introduced which will halve the amount of lead allowed in tap water.

Engineering specialists, Morrison Utility Services and Balfour Beatty, will carry out the project for us.

Lead in everyday life

Lead comes from many sources, such as car exhausts and old paintwork. It may also be naturally present in air, food, soil and water. Too much exposure to lead can be harmful to health.

While water from our treatment works may contain a trace of lead, it can absorb small traces of the metal if left to stand for a long time in lead supply pipes or internal plumbing.

How do I know if I have lead pipes?

If your home was built before 1970 it may have lead pipes – after that time it is unlikely because there was a change in building regulations. If you're unsure, you can make a simple check by following the advice below.

How we do refurbish the old pipe?

Usually, teams from our partners will dig just two holes, one at the boundary of your property and one at the point where the communication pipe connects into the water main in the street.

The communication pipe will then be refurbished between the two points. As they will be working on a number of pipes at the same time, there will be lots of holes open at the same time in your street.

If we find a number of other companies' pipes and cables in the way we may need to dig a larger, longer hole.

We'll fill in and reinstate the holes as soon as possible, usually within three days, but please be aware this may not always be possible.

How will the work affect you?

A team from either Balfour Beatty or Morrison Utility Services will be coming to your street soon.

You'll receive a warning card nearer the time to notify you when your water supply will be interrupted.

Figure. 56: Customer website advice.

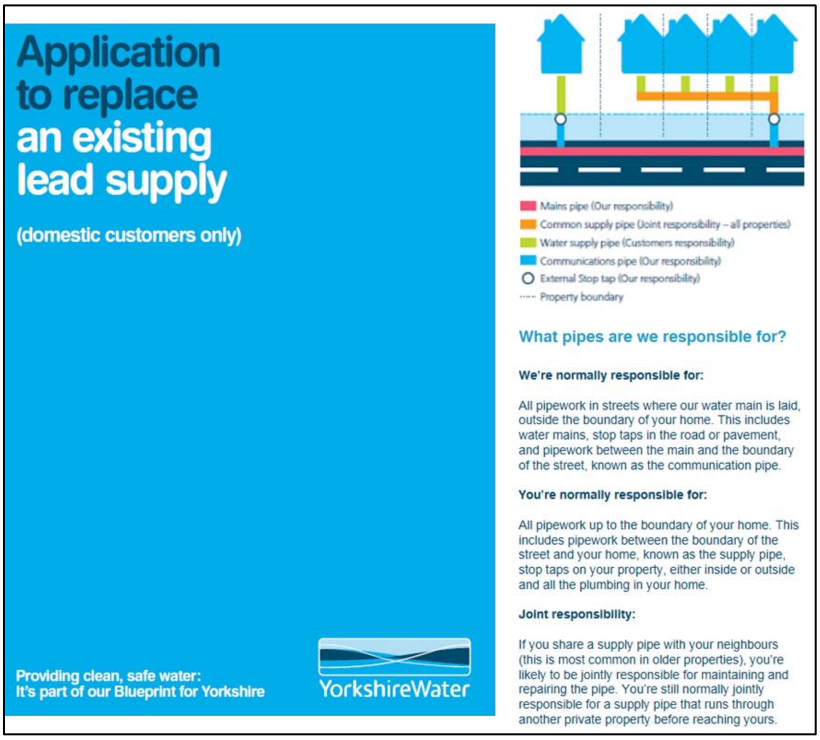

Figure. 57: Customer website advice on replacing lead pipework.

Opportunistic Replacement of Services

Throughout AMP7, as part of our leakage reduction strategy, we will focus on reducing leakage from service pipes. This will result in a more proactive approach to communication pipe replacement. This could result in a couple of possible outcomes. The first being that we replace communication pipes whilst we are carrying out the proactive replacement of distribution mains, or we have a proactive replacement strategy of communication pipes. Both options will inevitably benefit customers in relation to a reduced exposure to lead, as lead communication pipes will be replaced as part of the strategy.

Long Term

We have proposed a significant programme of work to continue progress toward compliance and seek DWI's support for this indicative activity. We recognise that this is a time of change for the Industry, its regulators and health professionals and are committed to working to deliver the information needed to support a future approach to lead.

We continue to invest in the deeper understanding of the chemistry and structure of the minerals which we rely on for plumbosolvency control as this will be needed, and its efficacy enhanced, until all lead sources are removed from service pipes and internal plumbing systems.

We have committed to undertaking trials which inform the future delivery of lead pipe remediation; we will aim to coordinate this across the Industry so that we gather the maximum intelligence to inform the future

2.7.9 Overall AMP7 proposals with investment requirements

We will continue to develop our Long-term Strategy for Water Quality and Acceptability over the early months of 2018; lead will be a key part of this activity and we are keen to work with the Inspectorate and others as we do so. We have a strong history of innovation in mitigating lead risk; as early adopters of phosphate dosing; and co-developers of a lining technique which gives further options to water companies to reduce exposure to lead.

As this submission precedes the development of the long-term strategy for lead we believe that it would be inappropriate to continue widespread communication pipe lining or replacement. The focus for AMP7 should be to undertake more targeted activity focusing on the following key areas:

- Vulnerable customers – those requiring continuous supply or registered for home dialysis.
- Failures at 10µg/l and above.
- Schools where the service pipe is of lead construction – subject to agreement with school "owners", for example Local Education Authorities or Academy Trusts.
- Lead Pipe Replacement on request by customers.
- Further large-scale trial(s) – for example to identify factors when remediating lead pipes in private rented and owner-occupied housing.
- Research and development into areas such as "extending the length capable of lining" and "novel approaches to lead pipe replacement".

We would welcome further discussion with DWI and others, to identify the best use of investment in this area of water quality enhancement for the future. We are pleased that a very long-term, inter-generational approach to lead has been proposed by DWI. We trust that this will be picked up by Ofwat, other government departments, and local and health authorities to facilitate real progress on this challenging subject.

Our AMP7 approach to lead has 5 main elements to it. These address specific areas of high risk, where Lead exceedances have occurred, where our customers are proactively addressing the lead risk and where we plan to invest to reduce the exposure of lead to those who are most at risk.

The is summarised below:

Table 47: Summary of lead pipe remediation schemes.

Lead Pipe Removal Schemes	Capex (£million)
Helping Hands	1.2
Education Establishments	0.9
Replace on sample failure	0.7
Customer requested	2.9
Hotspot DMAs	7.8*
Lead Trials	1.5
Total	15.0

*We may seek to swap expenditure out of the 'hot spot' programme to facilitate further trials to build our long-term strategy in collaboration with DWI.

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Part B - Annexes

Proposals to carry out improvements for Drinking Water Quality reasons

22nd December 2017

Chellow Heights WTW

Site details

Water Company:

Yorkshire Water Services Limited

Date of submission:

31st December 2017

Name of water Treatment Works/ Distribution System/ Service Reservoir/ other asset:

Chellow Heights WTW (T4691410).

Water quality hazard/ drivers identified:

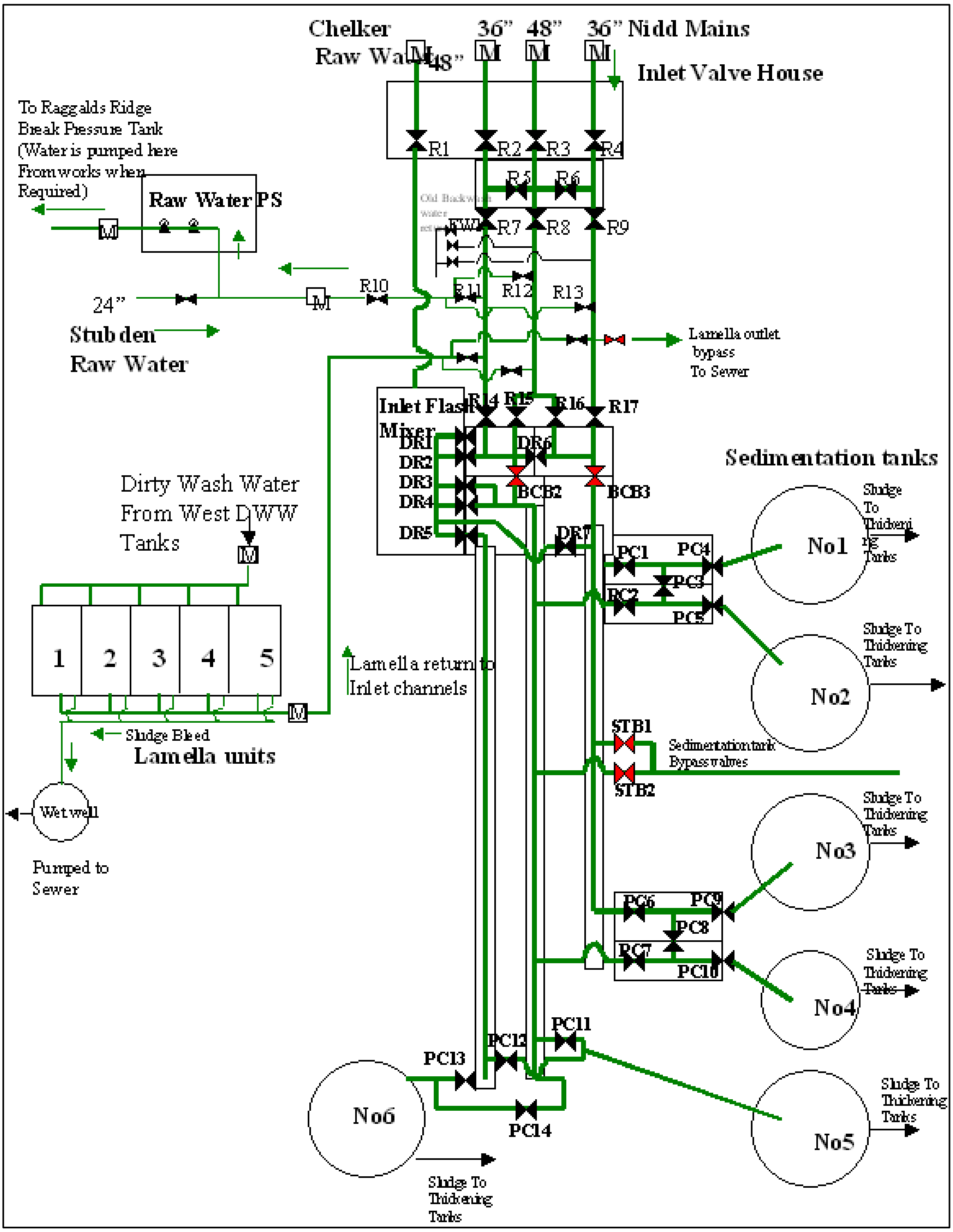
Raw water colour deterioration as a surrogate for disinfection by products (DBPs) generation risk and DBP minimisation.

Reference to outcome in company's long-term strategy:

Enhanced Drinking Water Quality

Stage One – Details of water treatment works and associated supply system

Provide supply arrangements and treatment works details:



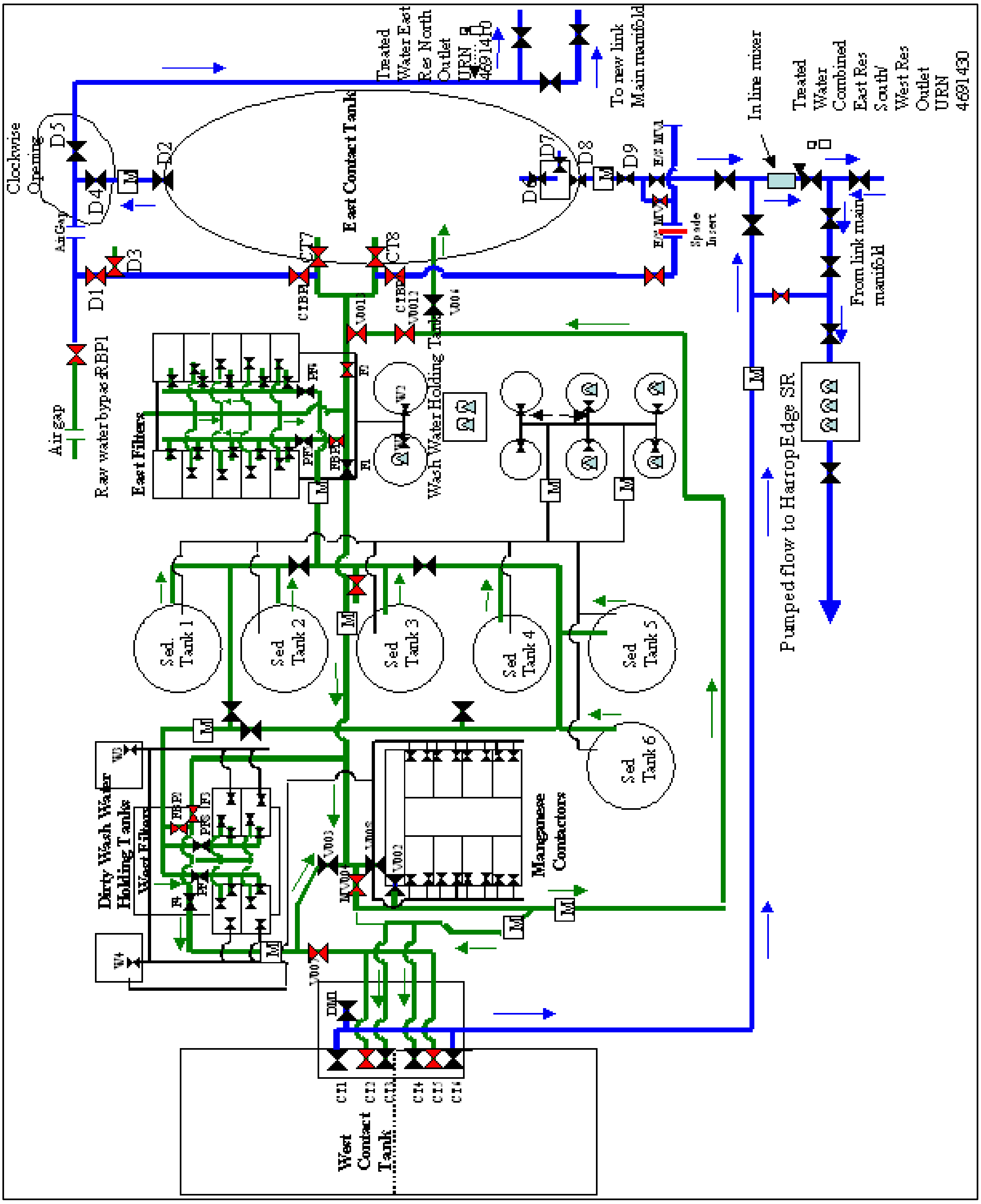


Figure. 1: Site schematic for Chellow Heights WTW.

Table 1:Two tables illustrating the design and current flow capacities of Chellow Heights WTW.

Design Flows (Ml/d)	**Minimum**	**Maximum**
Inlet Flow	90	207
Outlet Flow	-	175

Current Flows (Ml/d)	**Minimum**	**Average**	**Maximum**
Inlet Flow	101	142	200
Outlet Flow	90	140	205

There are no constraints on deployable output; the site output is limited to 175 Ml/d by the current capability of the inter-stage pumps between the RGFs and manganese contactors

Raw Water Sources

Chellow Heights WTW is routinely fed with raw water from the Chelker Pumping Main and the Nidd and Stubden Aqueducts. Due to the flexibility of the system, many raw water sources can feed into those aqueducts. A summary of raw water sources are as follows:

Table 2:Chellow Heights WTW - Raw water sources.

Source Name	**Source of Water**
Angram IRE	Impounding Reservoir
Scar House IRE	Impounding Reservoir
Nidd Aqueduct Intakes	Surface Direct abstraction
Upper Barden IRE	Impounding Reservoir
Washburn Valley	Impounding Reservoir
Chelker IRE	Impounding Reservoir
Lobwood RPS – River Wharfe	Surface Direct abstraction – to Chelker IRE
Stubden IRE	Impounding Reservoir
Thornton Moor IRE	Impounding Reservoir

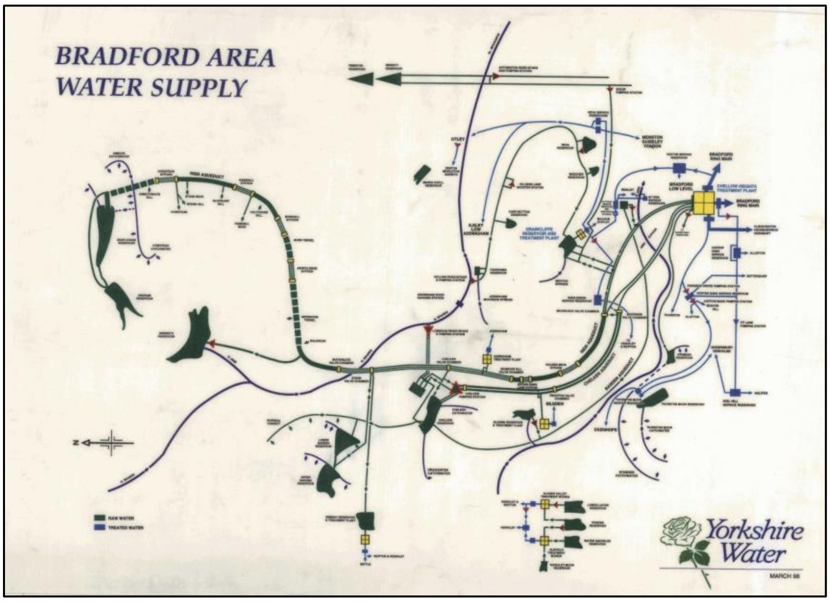


Figure. 2: Raw water sources schematic for Chellow Heights WTW and Bradford area.

Treatment Process

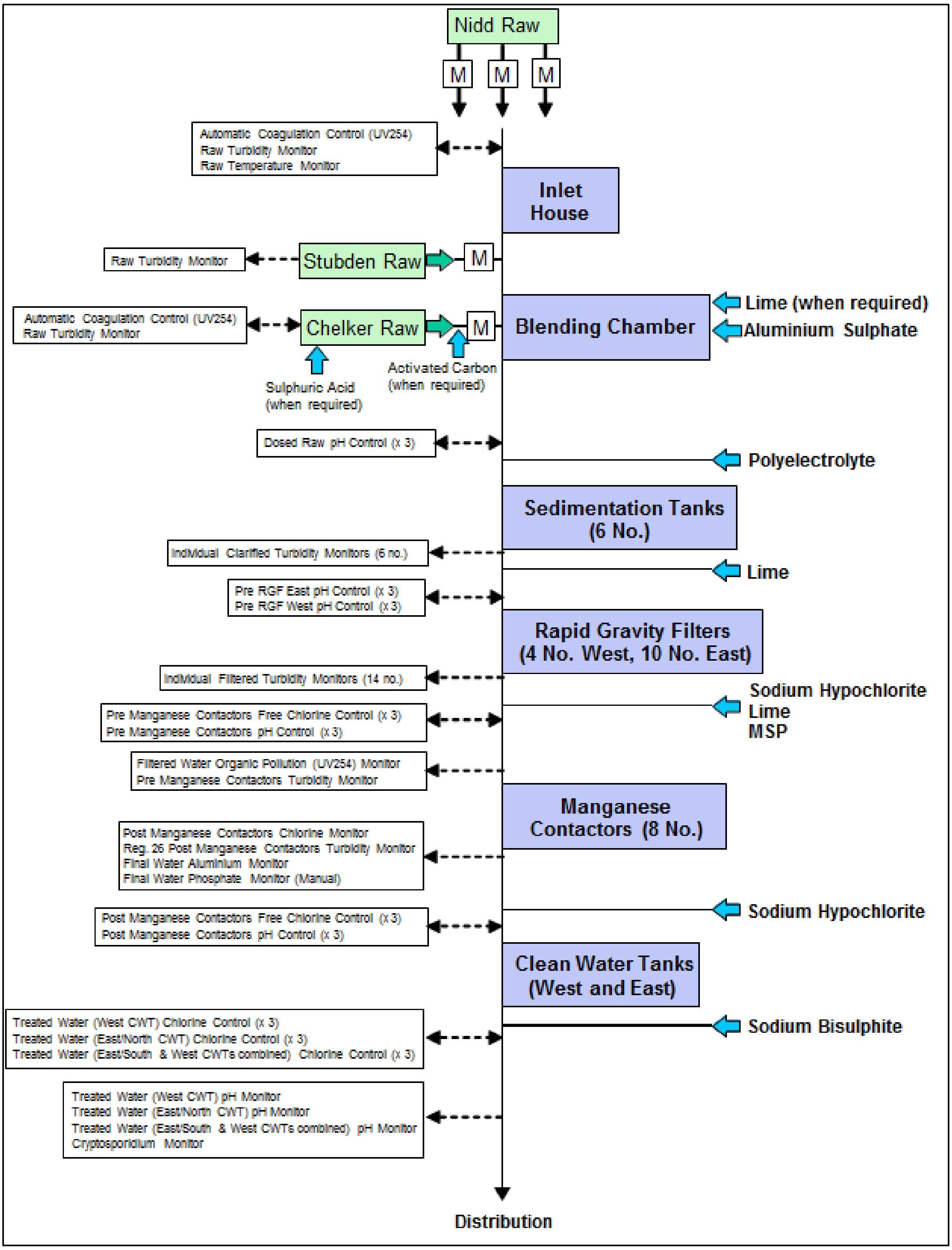


Figure. 3: Chellow Heights WTW process schematic.

The Nidd Aqueduct raw water enters via three mains to Chellow Heights WTW through a valve chamber. The water then enters three sand removal channels where heavy deposits are settled out. Aluminium sulphate is dosed to all three channels before the water mixes with the Chelker water. The combined 'dosed' water is then distributed to the six clarifiers. A dose of polymer is applied on the inlet to each clarifier. The coagulated material forms a sludge blanket approximately 4m from the tank surface and the accumulated sludge is bled off for further thickening.

The settled water passes over launders into the ring main and then onto the rapid gravity filters (RGFs). There are 14 RGFs in total (10 East and 4 West), responsible for the removal of solids from the clarified water. After filtration, lime is applied to each of the streams along with sodium hypochlorite. This dosed water passes onto eight manganese contactors responsible for the removal of precipitated manganese salts and any solids carried over from the RGFs. Disinfection with the further addition of sodium hypochlorite then takes place in the two on-site clean water tanks.

MSP is dosed to aid plumbosolvency in the distribution mains.

Service reservoirs

The distribution system fed by Chellow Heights WTW is extensive and complex and is liable to regular change. A summary of the distribution area fed from Chellow Heights WTW is as follows:

- Badger Hill SRE
- Bradford Intermediate Level
- Calverley SRE
- Causeway Break Pressure Tank
- Drighlington SRE
- Foxroyd SRE
- Gawthorpe SRE
- Harrop Edge SRE
- Hartshead Moor SRE
- Heaton SRE
- Horton Bank Top SRE
- Idle Hill SRE
- Morley Victoria SRE
- Owlcotes SRE
- Penfield SRE
- Soil Hill SRE
- Staincliffe SRE
- Thornton Moor SRE

Table 3: A table showing the water supply zones (WSZs) fed from Chellow Heights WTW.

WTW	Water Supply Zone	% WTW Supply	WSZ Ml/d	WSZ Population
Chellow Heights	Batley/Morley 2017	4.00%	5.72	73036
Chellow Heights	Bradford Central 2017	17.00%	24.29	92258
Chellow Heights	Bradford SE 2017	40.00%	57.16	99820
Chellow Heights	Bradford SW 2004	13.00%	18.58	88553
Chellow Heights	Dewsbury 2017	9.00%	12.86	60674
Chellow Heights	Idle/Pudsey 2004	5.00%	7.14	86372
Chellow Heights	Leeds HL Bramley/Headingley 2004	0.00%	0.00	424515
Chellow Heights	Morley Ossett 2017	6.00%	8.57	427531
Chellow Heights	Roils Head 2004	3.00%	4.29	406321
Chellow Heights	Shipley/Bingley 2004	3.00%	4.29	413267

Stage Two – Hazard identification and Risk Characterisation

Provide details of methodology used to identify hazards i.e. historic data, events/ incidents including near miss situations, operator knowledge, modelling and site visits/ technical audits:

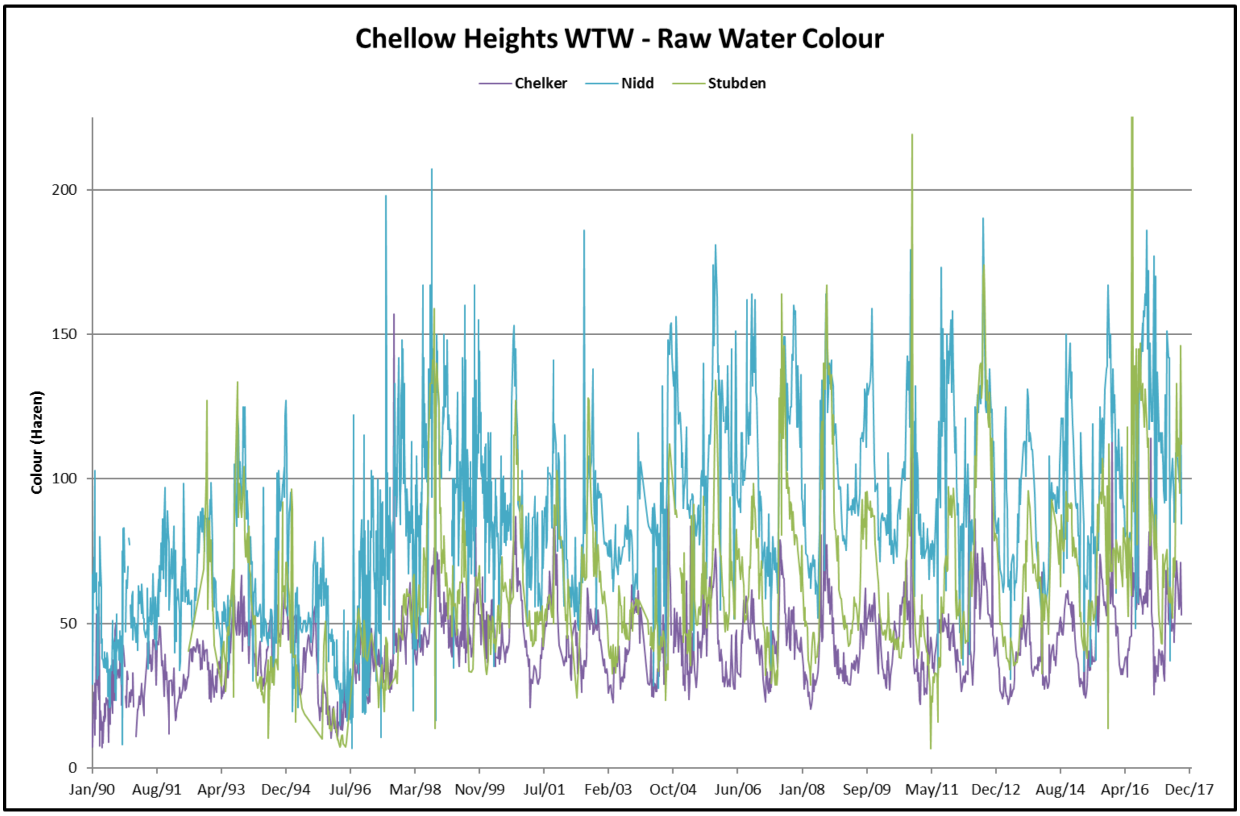


Figure. 4: Chart illustrating the raw water colour trend at Chellow Heights WTW.

Table 4:Average THM results from 2010 to 2016 from Chellow Heights WTW treated water.

Date	Count of THM total	Average of THM total
2010	91	39.94
2011	80	42.04
2012	79	41.18
2013	82	41.77
2014	81	45.29
2015	84	50.01
2016	80	43.08

Table 5: Average THM results from 2014 to 2016 from WSZs served by Chellow WTW.

	Average of Trihalomethanes total µg/l		
	2014	**2015**	**2016**
BRADFORD SW 2004 WSZ	49.91	57.09	49.50
BATLEY/MORLEY 2004 WSZ	51.90	55.32	47.73
IDLE/PUDSEY 2004 WSZ	46.21	54.31	47.37
MORLEY OSSETT 2004 WSZ	43.01	50.58	47.07
SHIPLEY/BINGLEY 2004 WSZ	44.45	53.86	43.97
BRADFORD SE 2004 WSZ	46.64	55.36	43.17

The risks as identified in the Regulation 28 report for Chellow Heights WTW are presented in table 6.

Table 6: Drinking Water Safety Planning (DWSP) risk assessment for Chellow Heights WTW.

Intolerable Risk
Current Intolerable Risks There are no current intolerable risks identified in Chellow Heights WTW.
Future Intolerable Risks **Risk ID:** 17490 (updated 20/06/2017) – Post risk score 23. **Chellow Heights WTW** - Failure to sufficiently treat raw water for colour and to prevent DBP formation. **Description** - There is an increasing trend for colour at Chellow Heights WTW - future intolerable risk identified. **Predicted Year** – Estimate 2041 for colour **Effect Area** – Water Quality **Risk** – Probability = Medium, Severity = Very High **Data available** – Historical water quality sample data, analysis of future trends.
Current Risks
Current Red risk **Risk ID:** 20707 (updated 18/09/2017) – Post risk score 24. **Chellow Heights WTW** – WQ issues due to start-up / shutdown of the works. **Description** - Lack of run to waste facility for the site **Effect Area** – Water Quality **Risk** – Probability = High, Severity = Very High

Current Amber risk

Risk ID: 17489 (updated 20/06/2017) – Post risk score 20.
Chellow Heights WTW – Failure to sufficiently treat raw water for colour and to prevent DBP formation.
Description - DBPs exceed DWI – Reg26 assessment criteria on occasion.
Effect Area – Water Quality
Risk – Probability = Low, Severity = Very High
Data available – Water quality sample data

Risk ID: 14638 (updated 20/06/2017) – Post risk score 20.
Chellow Heights WTW – Failure of pH control e.g. acid/lime/caustic.
Description – pH control
Effect Area – Water Quality
Risk – Probability = Low, Severity = Very High
Data available – Water quality sample data

Risk ID: 17314 (updated 05/09/2017) – Post risk score 20.
Chellow Heights WTW – Failure of treatment process to achieve final water turbidity within acceptable limits.
Description – Turbidity higher than Company's internal target at times.
Effect Area – Water Quality
Risk – Probability = Low, Severity = Very High
Data available – Water quality sample data

Table 7: A table identifying statistically significant trends in raw water colour.

	JAN 1998+							
	By MONTH				By YEAR			
Site	Max	Mean	Median	Min	Max	Mean	Median	Min
Chellow Heights Chelker	-0.321	-0.244	-0.244	-0.13	0.311	-0.176	-0.142	-0.1
Chellow Heights Nidd	-0.282	0.339	0.214	0.992	-0.833	-0.199	-0.121	1.83
	JAN 2004+							
	By MONTH				By YEAR			
Site	Max	Mean	Median	Min	Max	Mean	Median	Min
Chellow Heights Chelker	-0.12	0.096	0.179	0.39	-0.047	0.129	0.322	0.602
Chellow Heights Nidd	-1	-0.847	-0.938	-0.665	-1.414	-0.971	-0.841	1.684
KEY:	Highly sig (@1% level)	(@ 5% lev	Non sig					

Details of any events that have occurred in the catchment, WTW.

The following Events are associated with the Chellow WSS:

CHE - 17 2017 - 6146 Chellow Heights WTW - Reg 26 Turbidity - 15.07.2017

CHE - 16 2016 - 5498 Chellow Heights - Loss of Chlorination 09/04/2016

BRA 15 2015 - 4930 Bradford Cryptosporidiosis Cases - Enquiry from PHE 18/03/2015 – (NB - no link to water supply)

2010/2676 - Discolouration & loss of supplies - Clayton & Buttershaw, near Bradford, West Yorkshire – 5.03.2010

BRA 09 Bradford 30" Mains Burst 18/12/2009

Existing control measures – Catchment

Catchment restoration works has been completed in AMP5 in two catchment areas which supply Chellow Heights WTW – Upper Nidderdale (comprising the catchments of Lodge Moor, Riggs Moor, High West Moor) and Upper Barden (Barden Moor).

The work completed included the following activities:

- gully blocking
- gully reprofiling
- vegetation management, such as control of heather cutting and burning
- stabilising and raising the hydrology of the peat
- creation of pools to encourage the growth of peat-forming species, such as sphagnum moss
- bare peat restoration

The Upper Nidderdale area restored included:

- 50km of grip blocking and re-profiling
- 42km of haggs reprofiling
- 47 ha brash and seeding works

The Upper Barden area restored included:

- 1626 ha of restoration through;
  - grip blocking
  - re-profiling
  - haggs reprofiling

Additional work is being undertaken under a Higher-Level Stewardship (HLS) agreement via Natural England which involves a 10-year scheme for improving fencing and stock-exclusion within the Upper Nidderdale catchment (High West Moor). This will help to protect our works from local livestock, and secure the benefits for a longer period going forward.

Academic research suggests it could take 15-20 years for catchment management work to result in significant raw water colour improvements.

Monitoring catchment control measures

The Company's operational monitoring programme includes weekly samples for colour, etc. taken at the individual WTW inlets. Figure 4 displays the raw water colour results since 1990.

The Company commissioned the University of Leeds to provide update reports (dated March 2017), on their on-going monitoring programme detailing the changes occurring at the catchments following the work being undertaken. The impacts were assessed on both the hydrological functioning of the catchment, and of the water quality.

The monitoring programme began in August 2012 and focussed along the north and northwest sections of Upper Barden. This programme included 19 spot sampling sites located on tributaries along the northern edge of the reservoir and along the main stream entering the northwest corner of the reservoir.

For the High West catchment, data regarding water quality has been collected from 15 intakes through a series of previous projects since 2006. Data collection has not been continuous over that time. The frequency and continuity of sampling has altered depending on funding and priorities at the time. Water sampling commenced at new locations for High West in April 2013. These were designed to cover areas where restoration work took place in winter 2012/2013. Since April 2013 monthly sampling has occurred at all How Stean and High West locations apart from a sampling gap in 2015 from May-July.

Monitoring of the Stean Moor began in 2009 when 12 stream monitoring locations were operationalised based on the plans for grip blocking. Discharge was measured at all 12 locations from November 2009 and grab water sample collection initiated in March 2010. Storm sampling using autosamplers occurred at several of the sites. The Leeds report highlighted some mixed results of the interventions undertaken. At the Upper Barden catchment, it is noted that weather has been the main driver of changing DOC and colour levels. On the other hand, at the Upper Nidderdale catchment (at Stean Moor) the grip blocking undertaken does appear to have positively affected DOC and colour levels at peak times (noticeably reducing the autumn peaks compared to the control).

Details of any changes in practices or policy

No significant changes in the operation of the raw water systems associated with Chellow WTW have been made. The relative volume from each source is to a degree reactive in response to the antecedent weather conditions and to the consequent volume of water impounded in Scar House & Angram IREs. Any shortfall in volume is made up from the River Wharfe, via Chelker reservoir.

Details of any licence abstraction issues

None and there have been no changes to abstraction volumes

Reasons for the presence of the hazard

Leeds University have completed a report investigating the occurrence and future trends in raw water colour. The investigations concluded the following reasons for the presence of raw water colour.

Over the period 1987-2015, water colour increased significantly ($p<0.01$), by between 1.5 and 4.9 Hazen/year, at 10 of the 11 sites. In contrast, over the period 1998-2015, water colour only increased significantly ($p<0.05$), by between 0.5 and 1.4 Hazen/year, at 6 of the 14 sites. This shows that the greatest rise in water colour occurred between 1987 and 1998.

Water colour was suppressed at all sites during the drought of 1995 and for several years following the drought (1996 & 1997) before increasing to very high-water colour values in 1998. Although droughts will continue to have an impact on water colour in the future, it is unlikely to be as pronounced as that observed following the 1995 drought, which was a 1 in 200-year event and coincided with a period of rapid decline in sulphur deposition. Using linear regression modelling where multiple drivers were considered together, the most successful models in predicting colour Z-score over the period 1987-2015 were those that included SO_2 emissions and summer rainfall; explaining 88-97% ($p<0.001$) of the long-term trend in colour. Summer rainfall and SO_2 emissions were also successful, but to a lesser extent, in explaining colour variation over the period 1998-2015 at most sites (r^2= 71-96%, $p<0.001$ at 5 sites).

Both models (statistical and processes) show that the biggest increase in DOC/water colour was observed in the 1990s, as a result of declining SO_4 deposition which led to an increase in soil pH and therefore an increase in DOC solubility. Both models suggest that DOC/water colour (annual and monthly mean concentrations) will be similar in 2030 as they have been in the period 2010-2015, and that in the future climate change, in particular wet summers, will have a bigger impact in controlling DOC/water colour.

Stage 3 – Control Measures Required

Provide details of short, medium and long-term control measures i.e.

Details of short term actions

Optimisation of coagulant dose and coagulation pH

Raw Water source selection subject to the requirements of abstraction licences, available water in storage and control lines

Details of mid to long terms control measures

In addition to the catchment restoration completed in AMP5, those sites and Ramsgill Moor have been identified for further works in the Pennine PeatLIFE to include the next phase of restoration work such as sphagnum inoculation. Furthermore, the Ramsgill site also has HLS funding been spend on re-vegetating bare peat on the top part of site. This work will be completed over the next three winters and further resilience work is planned for AMP7. Recently parts of the catchments that supply Chellow Heights WTW as a collective, have been included in the bid for the £10m Defra Peatland Restoration fund. Several catchments feeding Chellow Heights WTW have been included in the Water Industry National Environment Programme (WINEP) to fund further repair and resilience activities. The action plan is to complete resilience work on Woo Gill Moor, Lodge Moor, Grimwith Moor, Barden Moor and High West Moor will include vegetation diversification and inoculation with sphagnum. This may also include increasing dam heights in gullies where repair activity has filled them up to the next level.

Table 8: Catchments submitted into WINEP scheme for Chellow Heights WTW.

Driver Description	WINEPID	Function	RBD	Area	Water Company	Unique ID	Scheme Name	Waterbody	Waterbody ID	Water Body Type(s)	WFD Catchment	Driver Code
Drinking Water Protected Areas	YOR00162	WQ	Humber	Yorkshire	Yorkshire Water Service Ltd	7YW200106	Scar House and Angram	Nidd from Source to Howstean Beck	GB104027068380	River	Nidd Upper	DrWPA_ND
Drinking Water Protected Areas	YOR00163	WQ	Humber	Yorkshire	Yorkshire Water Service Ltd	7YW200107	Angram	Nidd from Source to Howstean Beck	GB104027068380	River	Nidd Upper	DrWPA_ND
Drinking Water Protected Areas	YOR00164	WQ	Humber	Yorkshire	Yorkshire Water Service Ltd	7YW200108	Grimwith	Barben Beck/River Dibb Catchment (trib of Wharfe)	GB104027064120	River	Wharfe Upper	DrWPA_ND
Drinking Water Protected Areas	YOR00165	WQ	Humber	Yorkshire	Yorkshire Water Service Ltd	7YW200109	Barden Upper	Barden Beck Catchment (trib of Wharfe)	GB104027064060	River	Wharfe Middle and Washburn	DrWPA_ND
Drinking Water Protected Areas	YOR00166	WQ	Humber	Yorkshire	Yorkshire Water Service Ltd	7YW200110	How Stean	Howstean Beck from Source to River Nidd	GB104027068300	River	Nidd Upper	DrWPA_ND
Drinking Water Protected Areas	YOR00167	WQ	Humber	Yorkshire	Yorkshire Water Service Ltd	7YW200111	Ramsgill direct intake	Nidd from Howstean Beck to Ashfoldside Beck	GB104027068294	River	Nidd Upper	DrWPA_ND
Drinking Water Protected Areas	YOR00168	WQ	Humber	Yorkshire	Yorkshire Water Service Ltd	7YW200112	Upper Wharfedale Chelker	Wharfe from Oughtershaw Beck to Park Gill Beck	GB104027069290	River	Wharfe Upper	DrWPA_ND
Drinking Water Protected Areas	YOR00169	WQ	Humber	Yorkshire	Yorkshire Water Service Ltd	7YW200113	Stubden	Bridgehouse Beck from Source to River Worth	GB104027064200	River	Aire Middle	DrWPA_INV
Drinking Water Protected Areas	YOR00170	WQ	Humber	Yorkshire	Yorkshire Water Service Ltd	7YW200114	Thornton Moor	Bridgehouse Beck from Source to River Worth	GB104027064200	River	Aire Middle	DrWPA_ND
Drinking Water Protected Areas	YOR00171	WQ	Humber	Yorkshire	Yorkshire Water Service Ltd	7YW200115	Nidd intakes (direct)	Nidd from Howstean Beck to Ashfoldside Beck	GB104027068294	River	Nidd Upper	DrWPA_ND

Options the company has considered e.g. catchment management

The Company has been undertaking catchment management in the Upper Nidderdale area to begin the process of repairing the damaged peatland which dominates the catchment; however, this activity is likely to take between 10-20 years to stabilise colour levels from the impounding reservoirs, and longer to begin to improve them. Given the long-term and uncertain nature of the restoration of peatland it is unlikely that in the short to medium term this approach can be relied upon to deliver and sustain compliance for DBPs.

Catchment Management will be pursued in parallel with the proposed engineered solution as a means of ensuring that this is sustainable for the long-term, and over time the additional operating costs of the treatment solution can be reduced.

Capital costs and net additional operating costs

Table 9: Scheme costs for Chellow Heights WTW.

Site	Capex (£million)	Opex per annum (£million)
Chellow Heights WTW	£ 23.9	£ 1.1

Full details of how the company intends to assess and measure the benefits delivered.

Colour/DBPs

The Company will use 3 main techniques to demonstrate the benefits to water quality of the proposed solutions:

1. Continuation of the long-term monitoring of raw water quality for relevant parameters – to track the progress of catchment management and corroborate on line raw water monitoring. We are about to start work on an R&D project to identify potential solutions for real-time monitoring in locations where there is no power and communication infrastructure.
2. Use of on-line UV254 analysers (or similar) to track the DOC of incoming raw water, post MIEX, and blended raw waters – this will provide direct evidence of the amount of DOC being removed prior to coagulant dosing.
3. Structured network sampling for DBPs – currently planned to be THMs and HAAs – to include WTW outlet, SRE outlets, and customer tap samples to encompass the range of travel times within the extensive system supplied by Chellow WTW.

Run to Waste

The Company will provide standard details relating to the construction of the facility; once the exact solution is specified, the company will provide the detail of the commissioning plan to demonstrate the solution operates as designed.

Embsay WTW

Scheme details

Water Company:

Yorkshire Water Services Limited

Date of submission:

31st December 2017

Name of water Treatment Works/ Distribution System/ Service Reservoir/ Other asset:

Embsay WTW (T4692155).

Water quality hazard/ drivers identified:

Raw water colour deterioration as a surrogate for disinfection by products (DBPs) generation risk and DBP minimisation and *Cryptosporidium*.

Reference to outcome in company's long-term strategy:

Enhanced Drinking Water Quality

Stage One – Details of water treatment works and associated supply system

Provide supply arrangements and treatment works details:

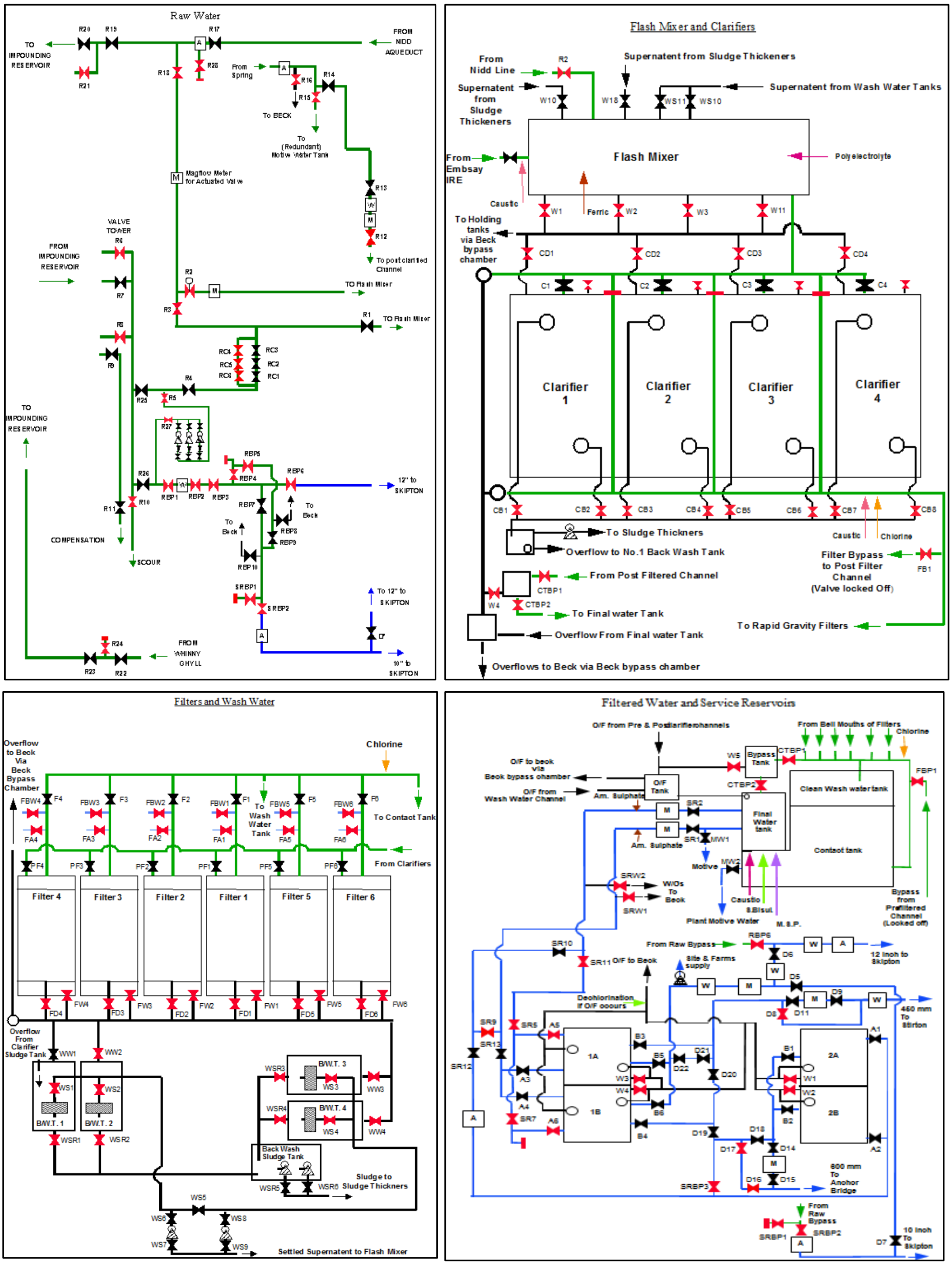


Figure. 5: Site schematic for Embsay WTW.

Table 10: Two tables illustrating the design and current flow capacities of Embsay WTW.

Design Flows (Ml/d)	Minimum	Maximum
Inlet Flow	-	-
Outlet Flow	-	24

Current Flows (Ml/d)	Minimum	Average	Maximum
Inlet Flow	14	17	23
Outlet Flow	13	17	24

Sources of raw water

Raw water is a combination of Embsay catchment area water, water fed via a pipeline off the Nidd Aqueduct and water pumped from Whinny Ghyll. A summary of the raw water sources are displayed in table 11.

Table 11:Raw water sources to Embsay WTW.

Source Name	Source of Water
Angram IRE	Impounding Reservoir
Scar House IRE	Impounding Reservoir
Nidd Aqueduct Intakes	Surface Direct abstraction
Upper Barden IRE	Impounding Reservoir
Embsay IRE	Impounding Reservoir
Whinny Ghyll	Impounding Reservoir

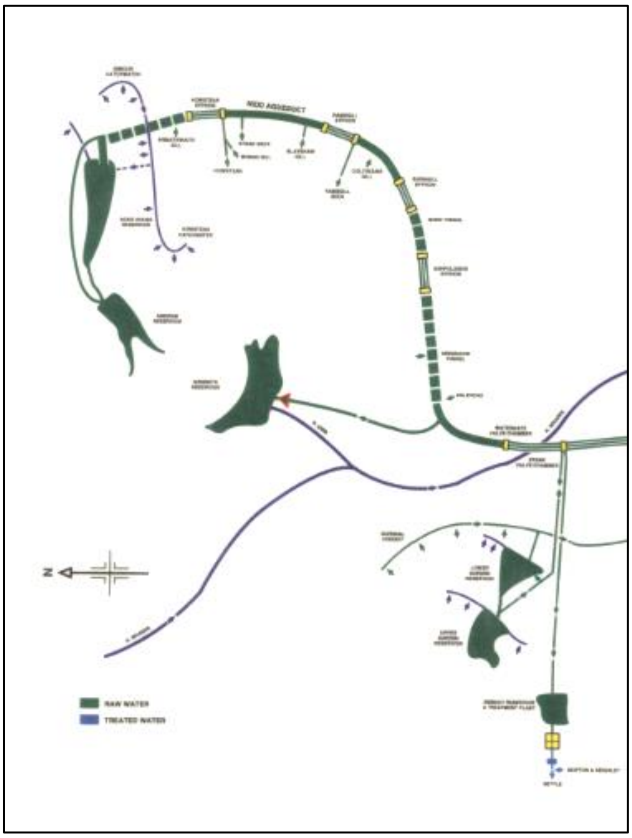


Figure. 6: Raw water source schematic for Embsay WTW.

Treatment process

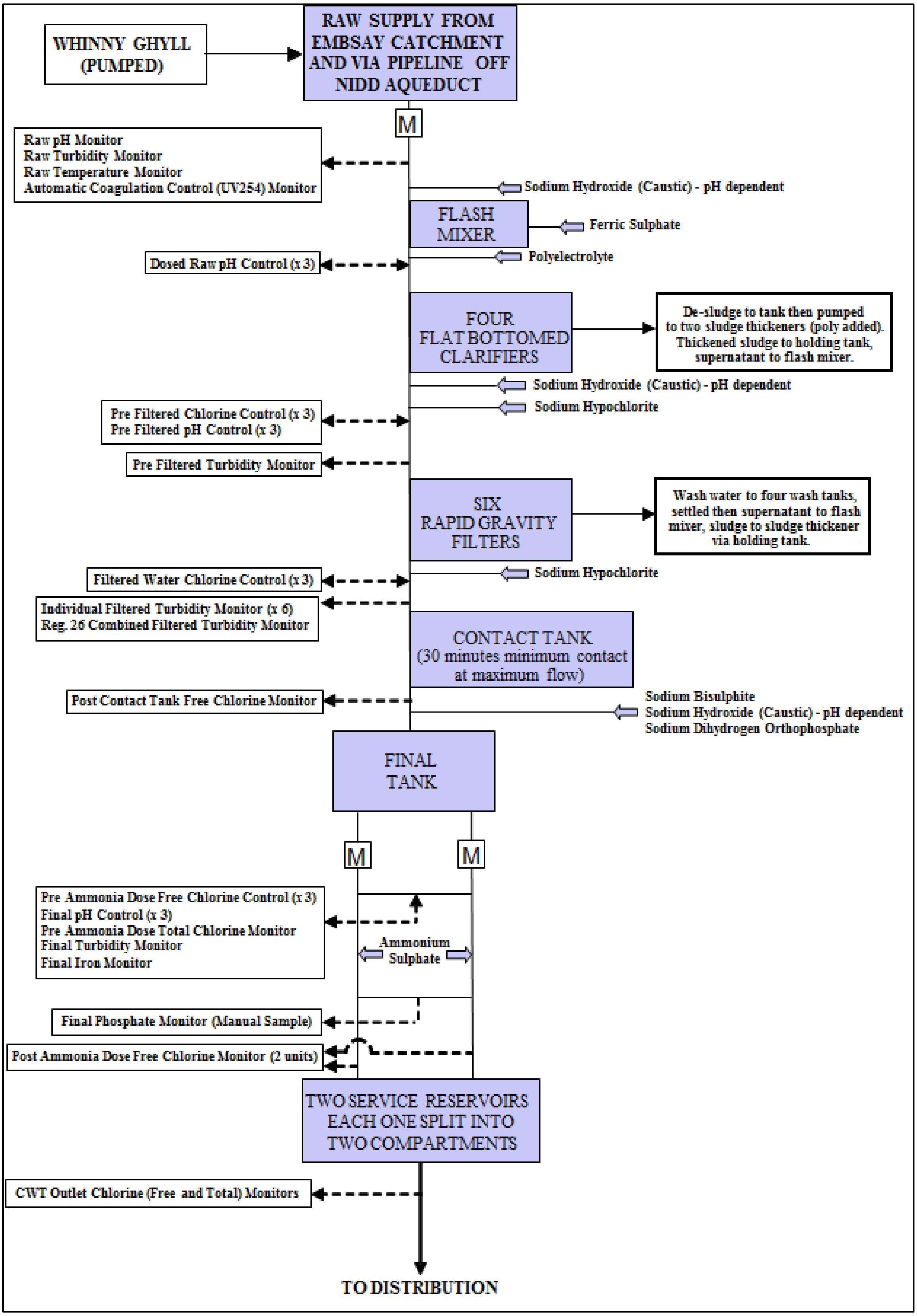


Figure. 7: Process schematic for Embsay WTW.

Raw water from Embsay impounding reservoir is transferred to the flash mixer via the valve tower and raw water inlet main.

A raw flow signal is fed from an indicator/transmitter located prior to the flash mixer and raw inlet valve. This signal provides the proportional to flow element for the dosing of ferric sulphate, dosed raw polyelectrolyte, dosed raw and pre-filtered caustic, and pre-filtered chlorine.

The caustic dose is controlled via a dosed raw pH unit which takes its sample from the end of the flash mixer. A dose of ferric sulphate is added approximately half way into the flash mixer. Polyelectrolyte is added as the dosed raw water weirs over from the flash mixer into the clarifier inlet channel. The dosed raw water is fed via the clarifier inlet channel into the flat-bottomed clarifiers. A high-level blanket alarm is fitted to each clarifier. Two sludge cones per clarifier are used to collect sludge in the clarifiers.

Water from the clarifiers flow into a filter inlet channel. Prior to water entering the filters, a dose of caustic soda and chlorine is added. Water passes into the rapid gravity filters. The filtered water passes via a common filtered outlet channel into a contact tank. A dose of chlorine is added to the filtered water prior to the contact tank. After passing through the contact tank, a dose of caustic soda is added to raise the pH to its final sample parameter target. MSP is also dosed at this point for plumbosolvency and sodium bisulphite is dosed to reduce the chlorine residual. Ammonium sulphate is dosed proportional to chlorine levels from this CRIT into the two outlet mains in order to achieve chloraminated water in distribution.

The proportional flow element to the post filtered chlorine, final caustic, MSP, sodium bisulphite and ammonium sulphate doses is achieved via a final combined flow signal taken from flow transmitters on each of the final water mains. Treated water is gravity fed to the two service reservoirs.

Service reservoirs

Treated water from Embsay WTW supplies two service reservoirs that supply the following distribution areas:

- Skipton
- West Craven (Earby, Barnoldswick)
- Villages and outlying areas to the East of Embsay
- Wharfe Valley to Buckden
- Aire Valley to Glusburn
- Ribble Valley to Ingleton

Table 12: A table showing the water supply zones (WSZs) fed from Embsay WTW.

WTW	Water Supply Zone	% WTW Supply	WSZ Ml/d	WSZ Population
Embsay	Keighley 2004	2.70%	0.47	73481
Embsay	Skipton/Craven 2015	97.30%	16.78	65563

Stage Two – Hazard identification and Risk Characterisation

Provide details of methodology used to identify hazards i.e. historic data, events/ incidents including near miss situations, operator knowledge, modelling and site visits/ technical audits:

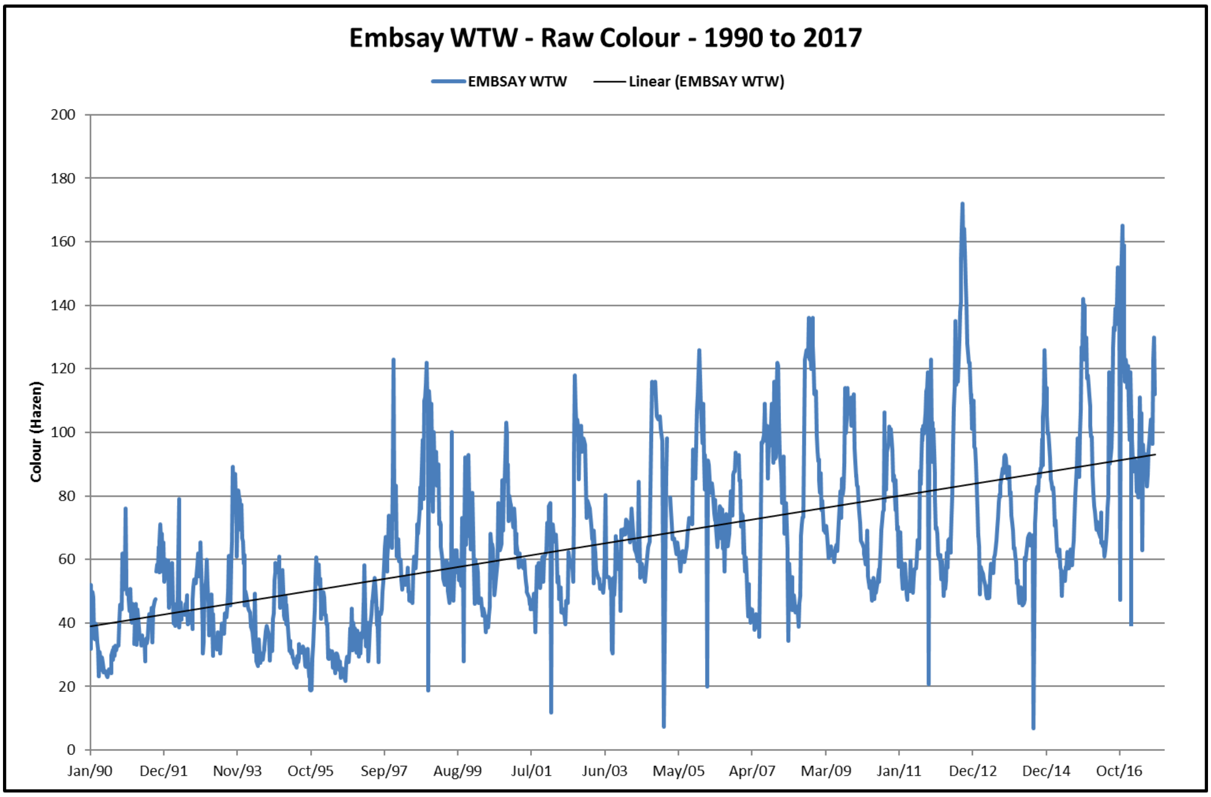


Figure. 8: Historic raw water colour at Embsay WTW.

Table 13: WSZ THM's for Embsay WTW 2010 to 2017.

WSZ	Year	No of Samples	Average
KEIGHLEY 2004 WSZ	2016	8	51.42
	2015	8	47.74
	2014	8	44.80
	2013	8	41.87
	2012	8	50.03
	2011	8	47.34
	2010	8	48.78

SKIPTON/CRAVEN 2015 WSZ	2016	8	32.13
	2015	8	37.26
	2014	10	34.86
	2013	11	30.58
	2012	10	36.72
	2011	10	28.58
	2010	11	21.91

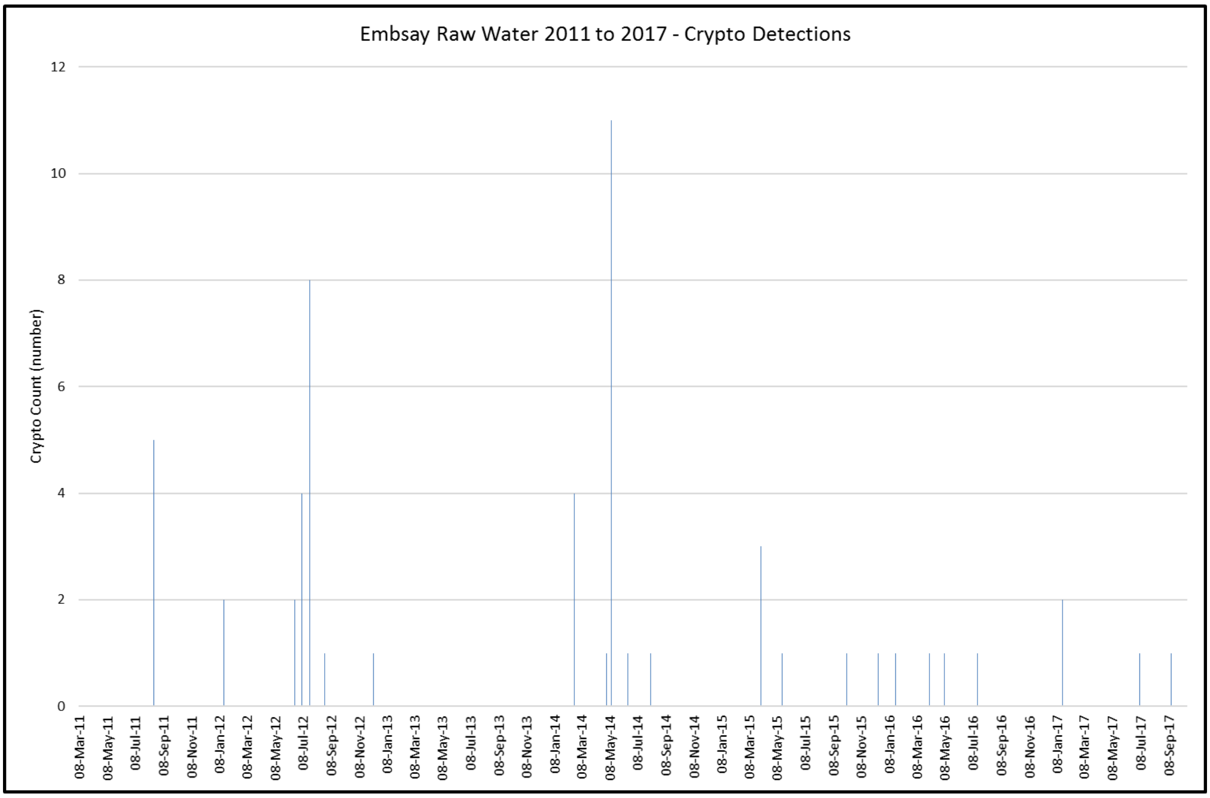


Figure. 9: Raw water crypto detections in raw water at Embsay WTW.

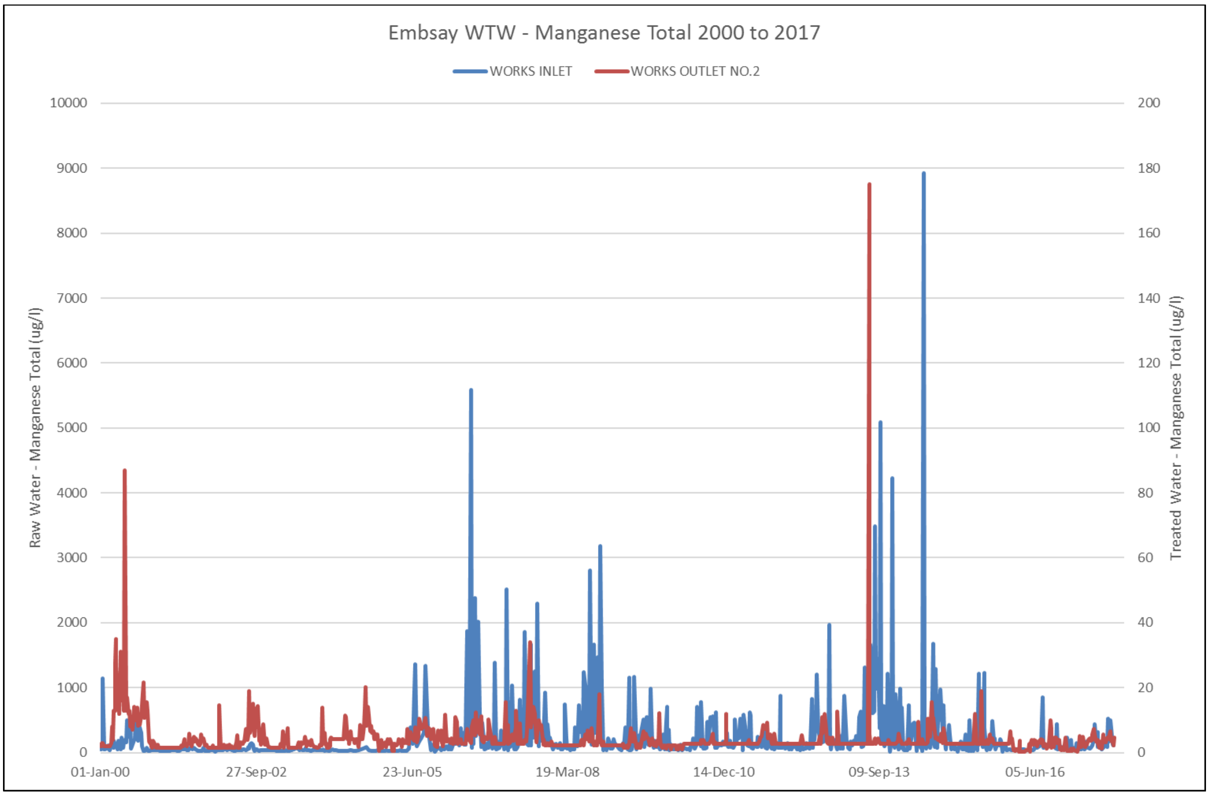


Figure. 10: Raw and treated water manganese total from 2000 to 2017 at Embsay WTW.

The risks as identified in the Regulation 28 report for Embsay WTW are presented in table 14.

Table 14: Drinking Water Safety Planning (DWSP) risk assessment for Embsay WTW.

Intolerable Risk
Current Intolerable Risks There are no current intolerable risks identified in Embsay WTW.
Future Intolerable Risks of concern **Risk ID –** 17455 (updated 09/05/2017) – Post risk score - 20 **Embsay WTW** - Failure to sufficiently treat raw water for colour and to prevent DBP formation. **Description** - There is an increasing trend for colour at Embsay WTW - future intolerable risk identified. **Predicted Year** – AMP10 for colour **Effect Area** – Water Quality **Risk** – Probability = Low, Severity = Very High **Data available** – Historical water quality sample data, analysis of future trends.
Current Risks
Current Amber Risks **Risk ID –** 14152 (updated 25/05/2017) – Post risk score - 20 **Embsay WTW** – Failure of the integrity of treated water storage. **Description** - Contact tank in poor condition. **Effect Area** – Water Quality **Risk** – Probability = Low, Severity = Very High **Risk ID –** 14148 (updated 23/06/2017) – Post risk score - 19

Embsay WTW – Failure of DWW handling
Description – No run to waste facility.
Effect Area – Water Quality
Risk – Probability = Medium, Severity = High

Risk ID – 8730 (updated 23/06/2017) – Post risk score - 20
Embsay WTW – Failure of treatment process to control manganese levels entering supply.
Description – Mn standard would be exceeded if there was no mitigation.
Effect Area – Water Quality
Risk – Probability = Low, Severity = Very High

Details of any other data relevant to hazard identified

Table 15: A table identifying statistically significant trends in raw water colour.

	JAN 1998+							
	By MONTH				By YEAR			
Site	Max	Mean	Median	Min	Max	Mean	Median	Min
Embsay	0.783	0.773	0.779	0.841	1.733	0.863	0.821	0.9

	JAN 2004+							
	By MONTH				By YEAR			
Site	Max	Mean	Median	Min	Max	Mean	Median	Min
Embsay	0.058	-0.008	-0.095	-0.081	1	0.111	0.034	-0.033

KEY:	Highly sig (@1% level)	Sig (@ 5% level)	Non sig

Summary of consumer complaints. - None
Details of any events that have occurred in the catchment, WTW. -
Details of any existing control measures that might influence the values.

Existing control measures – Catchment

Catchment restoration works has been completed in AMP5 in two catchment areas which supply Embsay WTW – Upper Nidderdale (comprising the catchments of Lodge Moor, Riggs Moor, High West Moor) and Upper Barden (Barden Moor).

The work completed included the following activities:

- gully blocking
- gully reprofiling
- vegetation management, such as control of heather cutting and burning
- stabilising and raising the hydrology of the peat
- creation of pools to encourage the growth of peat-forming species, such as sphagnum moss
- bare peat restoration

The Upper Nidderdale area restored included:

- 50km of grip blocking and re-profiling
- 42km of haggs reprofiling
- 47 ha brash and seeding works

The Upper Barden area restored included:

- 1626 ha of restoration through;
  - grip blocking
  - re-profiling
  - haggs reprofiling

Additional work is being undertaken under a Higher-Level Stewardship (HLS) agreement via Natural England which involves a 10-year scheme for improving fencing and stock-exclusion within the Upper Nidderdale catchment (High West Moor). This will help to protect our works from local livestock, and secure the benefits for a longer period going forward.

Academic research suggests it could take 15-20 years for catchment management work to result in significant raw water colour improvements.

Monitoring catchment control measures

The Company's operational monitoring programme includes weekly samples for colour, etc. taken at the individual WTW inlets. Figure 3 displays the raw water colour results since 1990.

The Company commissioned the University of Leeds to provide update reports (dated March 2017), on their on-going monitoring programme detailing the changes occurring at the catchments following the work being undertaken. The impacts were assessed on both the hydrological functioning of the catchment, and of the water quality.

The monitoring programme began in August 2012 and focussed along the north and northwest sections of Upper Barden. This programme included 19 spot sampling sites located on tributaries along the northern edge of the reservoir and along the main stream entering the northwest corner of the reservoir.

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Details of any changes in practices or policy. None

Details of any licence abstraction issues. None

Reasons for the presence of the hazard

Leeds University have completed a report investigating the occurrence and future trends in raw water colour. The investigations concluded the following reasons for the presence of raw water colour.
Over the period 1987-2015, water colour increased significantly ($p<0.01$), by between 1.5 and 4.9 Hazen/year, at 10 of the 11 sites. In contrast, over the period 1998-2015, water colour only increased significantly ($p<0.05$), by between 0.5 and 1.4 Hazen/year, at 6 of the 14 sites. This shows that the greatest rise in water colour occurred between 1987 and 1998.

Water colour was suppressed at all sites during the drought of 1995 and for several years following the drought (1996 & 1997) before increasing to very high-water colour values in 1998. Although droughts will continue to have an impact on water colour in the future, it is unlikely to be as pronounced as that observed following the 1995 drought, which was a 1 in 200-year event and coincided with a period of rapid decline in sulphur deposition.
Using linear regression modelling where multiple drivers were considered together, the most successful models in predicting colour Z-score over the period 1987-2015 were those that included SO_2 emissions and summer rainfall; explaining 88-97% ($p<0.001$) of the long-term trend in colour. Summer rainfall and SO_2 emissions were also successful, but to a lesser extent, in explaining colour variation over the period 1998-2015 at most sites (r^2= 71-96%, $p<0.001$ at 5 sites).

Both models (statistical and processes) show that the biggest increase in DOC/water colour was observed in the 1990s, as a result of declining SO_4 deposition which led to an increase in soil pH and therefore an increase in DOC solubility. Both models suggest that DOC/water colour (annual and monthly mean concentrations) will be similar in 2030 as they have been in the period 2010-2015, and that in the future climate change, in particular wet summers, will have a bigger impact in controlling DOC/water colour.

Outline Risk characterisation:

Where score sits in risk profile for supply system.

Stage 3 – Control Measures Required

Provide details of short, medium and long-term control measures i.e.

Details of mid to long terms control measures

In addition to the catchment restoration completed in AMP5, those sites and Ramsgill Moor have been identified for further works in the Pennine PeatLIFE to include the next phase of restoration work such as sphagnum inoculation. Furthermore, the Ramsgill site also has HLS funding been spend on re-vegetating bare peat on the top part of site. This work will be completed over the next three winters and further resilience work is planned for AMP7 for both Barden and Embsay Moor. Recently parts of the catchments that supply Embsay WTW as a collective, have been included in the bid for the £10m Defra Peatland Restoration Fund. By 2020 phase two resilience work will be completed within the Embsay Moor catchment which will include vegetation diversification and inoculation with sphagnum moss.

Several catchments feeding Embsay WTW have been included in the Water Industry National Environment Programme (WINEP) to fund further repair and resilience activities. The action plan is to complete resilience work on Woo Gill Moor, Lodge Moor, Barden Moor, Embsay Moor and High West Moor will include vegetation diversification and inoculation with sphagnum. This may also include increasing dam heights in gullies where repair activity has filled them up to the next level.

Table 16: Catchments included in WINEP for Embsay WTW.

Driver Description	WINEPID	Function	RBD	Area	Water Company	Unique ID	Scheme Name	Waterbody	Waterbody ID	Water Body Type(s)	WFD Catchment	Driver Code
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Drinking Water Protected Areas	YOR00163	WQ	Humber	Yorkshire	Yorkshire Water Service Ltd	7YW200107	Angram	Nidd from Source to Howstean Beck	GB1040270 68380	River	Nidd Upper	DrWPA_ND
Drinking Water Protected Areas	YOR00165	WQ	Humber	Yorkshire	Yorkshire Water Service Ltd	7YW200109	Barden Upper	Barden Beck Catchment (trib of Wharfe)	GB1040270 64060	River	Wharfe Middle and Washburn	DrWPA_ND
Drinking Water Protected Areas	YOR00166	WQ	Humber	Yorkshire	Yorkshire Water Service Ltd	7YW200110	How Stean	Howstean Beck from Source to River Nidd	GB1040270 68300	River	Nidd Upper	DrWPA_ND
Drinking Water Protected Areas	YOR00167	WQ	Humber	Yorkshire	Yorkshire Water Service Ltd	7YW200111	Ramsgill direct intake	Nidd from Howstean Beck to Ashfoldside Beck	GB1040270 68294	River	Nidd Upper	DrWPA_ND
Drinking Water Protected Areas	YOR00171	WQ	Humber	Yorkshire	Yorkshire Water Service Ltd	7YW200115	Nidd intakes (direct)	Nidd from Howstean Beck to Ashfoldside Beck	GB1040270 68294	River	Nidd Upper	DrWPA_ND
Drinking Water Protected Areas	YOR00190	WQ	Humber	Yorkshire	Yorkshire Water Service Ltd	7YW200134	Embsay catchment	Haw Beck from Source to Eller beck	GB1040270 63060	River	Aire Upper	DrWPA_ND

Options the company has considered e.g. catchment management

The Company has been undertaking catchment management in the Upper Nidderdale area to begin the process of repairing the damaged peatland which dominates the catchment; however, this activity is likely to take between 10-20 years to stabilise colour levels from the impounding reservoirs, and longer to begin to improve them. Given the long-term and uncertain nature of the restoration of peatland it is unlikely that in the short to medium term this approach can be relied upon to deliver and sustain compliance for DBPs.

Catchment Management will be pursued in parallel with the proposed engineered solution as a means of ensuring that this is sustainable for the long-term, and over time the additional operating costs of the treatment solution can be reduced.

Capital costs and net additional operating costs

Table 17: Costs for Embsay scheme.

Site	Capex (£million)	Opex per annum (£million)
Embsay WTW	£ 8.0	£ 0.1

Full details of how the company intends to assess and measure the benefits delivered

Colour/DBPs

The Company will use 3 main techniques to demonstrate the benefits to water quality of the proposed solutions:

1. Continuation of the long-term monitoring of raw water quality for relevant parameters – to track the progress of catchment management and corroborate on line raw water monitoring. We are about to start work on an R&D project to identify potential solutions for real-time monitoring in locations where there is no power and communication infrastructure.
2. Use of on-line UV254 analysers (or similar) to track the DOC of incoming raw water, post MIEX, and blended raw waters – this will provide direct evidence of the amount of DOC being removed prior to coagulant dosing.
3. Structured network sampling for DBPs – currently planned to be THMs and HAAs – to include WTW outlet, SRE outlets, and customer tap samples to encompass the range of travel times within the system supplied by Embsay WTW.

Fixby WTW

Scheme details

Water Company:

Yorkshire Water Services Limited

Date of submission:

31st December 2017

Name of water Treatment Works/ Distribution System/ Service Reservoir/ Other asset:

Fixby WTW (T4692305).

Water quality hazard/ drivers identified:

Raw water colour deterioration as a surrogate for disinfection by products (DBPs) generation risk and DBP minimisation. Improve mixing/coagulation dosing / enhance DAF / add RGF.

Reference to outcome in company's long-term strategy:

Enhanced Drinking Water Quality

Stage One – Details of water treatment works and associated supply system

Provide supply arrangements and treatment works details:

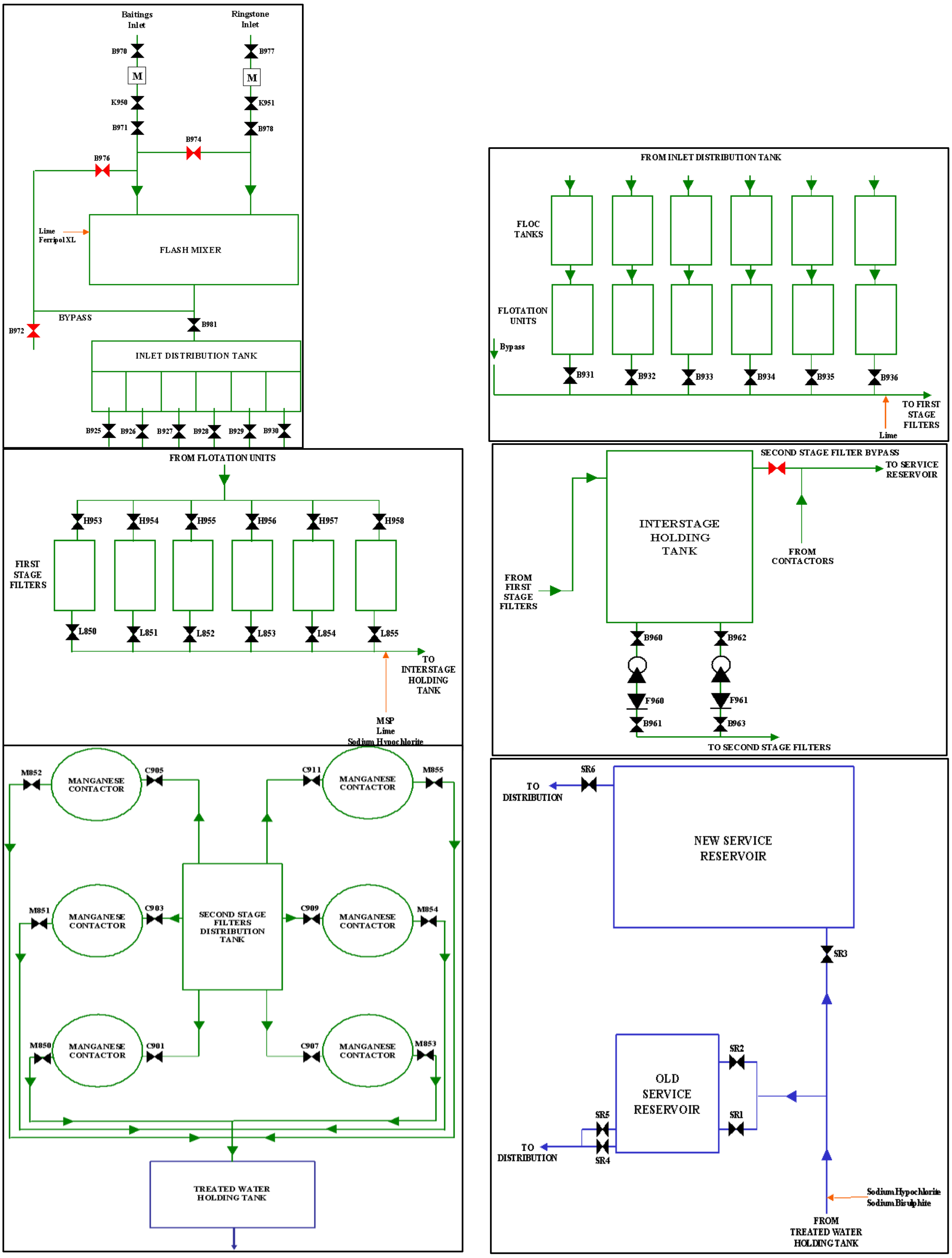


Figure. 11: Site schematic for Fixby WTW.

Table 18: Two tables illustrating the design and current flow capacities of Fixby WTW.

Design Flows (Ml/d)	**Minimum**	**Maximum**
Inlet Flow		
Outlet Flow	10	33

Current Flows (Ml/d)	**Minimum**	**Average**	**Maximum**
Inlet Flow	2.14	22.83	30.89
Outlet Flow	7.54	21.02	29.48

Sources of raw water

Fixby WTW is fed from four impounding reservoirs.

Table 19: Fixby WTW raw water sources.

Source Name	**Source of Water**
Ringstone IRE	Impounding Reservoir
Scammonden IRE	Impounding Reservoir
Boothwood IRE	Impounding Reservoir
Baitings IRE	Impounding Reservoir

Figure. 12:Fixby WTW raw water sources location.

Treatment process

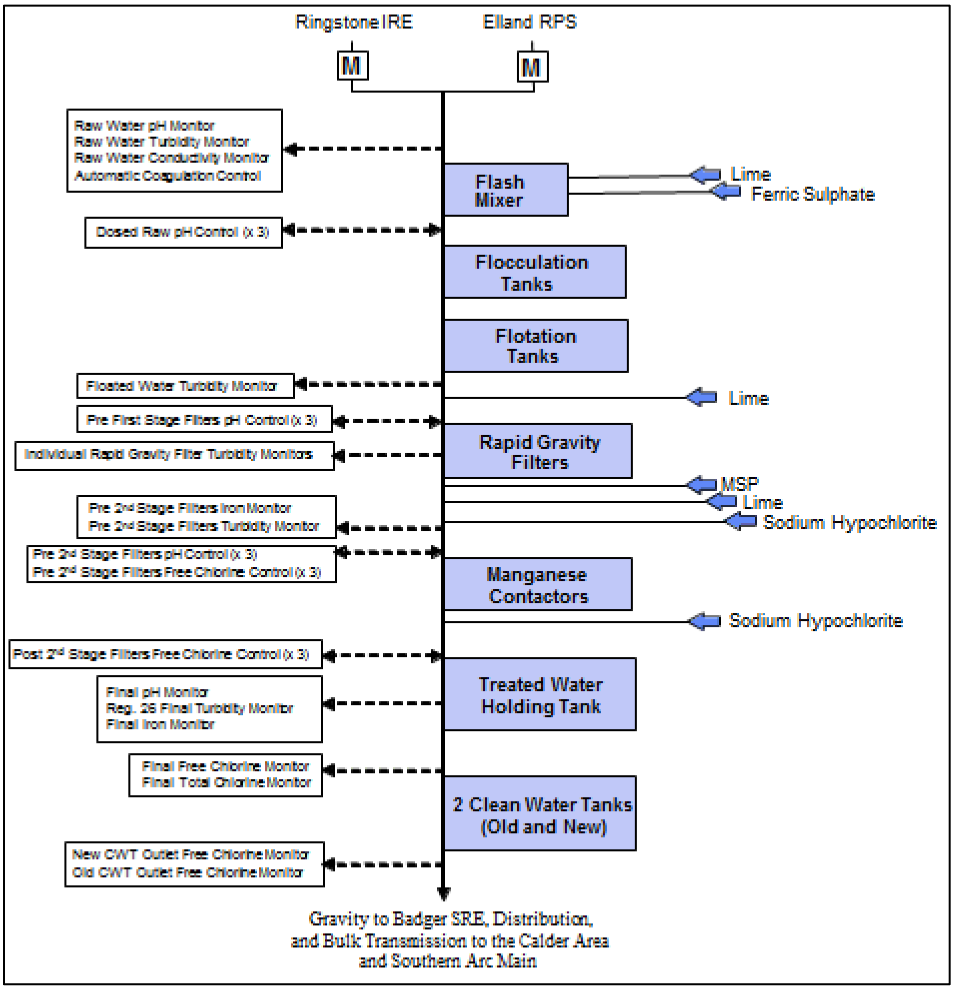


Figure. 13: Process Schematic for Fixby WTW.

Raw water enters the works through two cast iron mains. One main from Ringstone Reservoir, the other from Elland Upper Edge Pumping Station. On entry to the works, the two mains flow through isolation valves which are hand operated and then through electrically operated flow control valves. Before entering the flash mixer, the individual raw water supplies are monitored using flow meters.

The inlet raw water lime injection point and the addition of Feripol XL, together with the wash water return spray bar, are housed within the flash mixer. The chemicals and water are thoroughly mixed with the use of three mechanical mixers.

Raw water flows from the flash mixer via a six-way distribution tank into six dual compartment flocculator units each compartment containing two mechanical flocculators. Water leaves the flocculators from behind a submerged wooden baffle board arrangement and three outlet pipes and is directed into each flotation tank respectively.

Dissolved air is injected into the process stream by the flow of saturated recycled water. Dissolved air is released from solution forming fine bubbles which attach themselves to the floc forcing it to the surface. Floated sludge is removed by a scraper mechanism on each flotation unit. The sludge is discharged to sewer via a collection trough.

Clarified water flows under the scraper beach into the outlet channel, where it overflows via the flotation outlet weirs and on to a common channel. An overflow channel to waste is built such to prevent backing up through the process. The clarified water flows through a pipework arrangement to which there is a lime injection point for pH correction prior to first stage filtration. The pH corrected water is directed to six first stage rapid gravity filters.

Upon leaving the first stage filters, monosodium phosphate is added for plumbosolvency control into the combined filtered water channel. The water is then directed to a contact tank where lime, for pH correction, and sodium hypochlorite, for the oxidisation of manganese, are added. A continuously pumped sample is taken to monitor these dosing levels. The sodium hypochlorite dosing system operates in dual redundancy mode. Water is directed (via two low lift pumps) to the second stage filters (manganese contactors).

Water from the second stage filters flow into the treated water tank. Water entering the treated water tank is continually monitored for free chlorine residual, turbidity, pH and manganese. The treated water free residual may be trimmed upon entering the treated water tank by using triple validation to dose sodium hypochlorite/sodium bisulphite respectively. The treated water is directed over an outlet weir to the clean water tanks. Water is continuously pumped from the works outlet and is monitored for free chlorine residual and pH.

Service reservoirs

Water leaves the clean water tanks and gravitates to Badger Hill SRE and distribution via the Southern Arc Main.

Table 20: A table showing the water supply zones (WSZs) fed from Fixby WTW.

WTW	Water Supply Zone	% WTW Supply	WSZ Ml/d	WSZ Population
Fixby	Brighouse 2004	65.22%	12.70	85114
Fixby	Dewsbury 2017	0.80%	0.16	60674
Fixby	Wakefield City South and SAM 2017	33.99%	6.62	95810

Stage Two – Hazard identification and Risk Characterisation

Provide details of methodology used to identify hazards i.e. historic data, events/ incidents including near miss situations, operator knowledge, modelling and site visits/ technical audits:

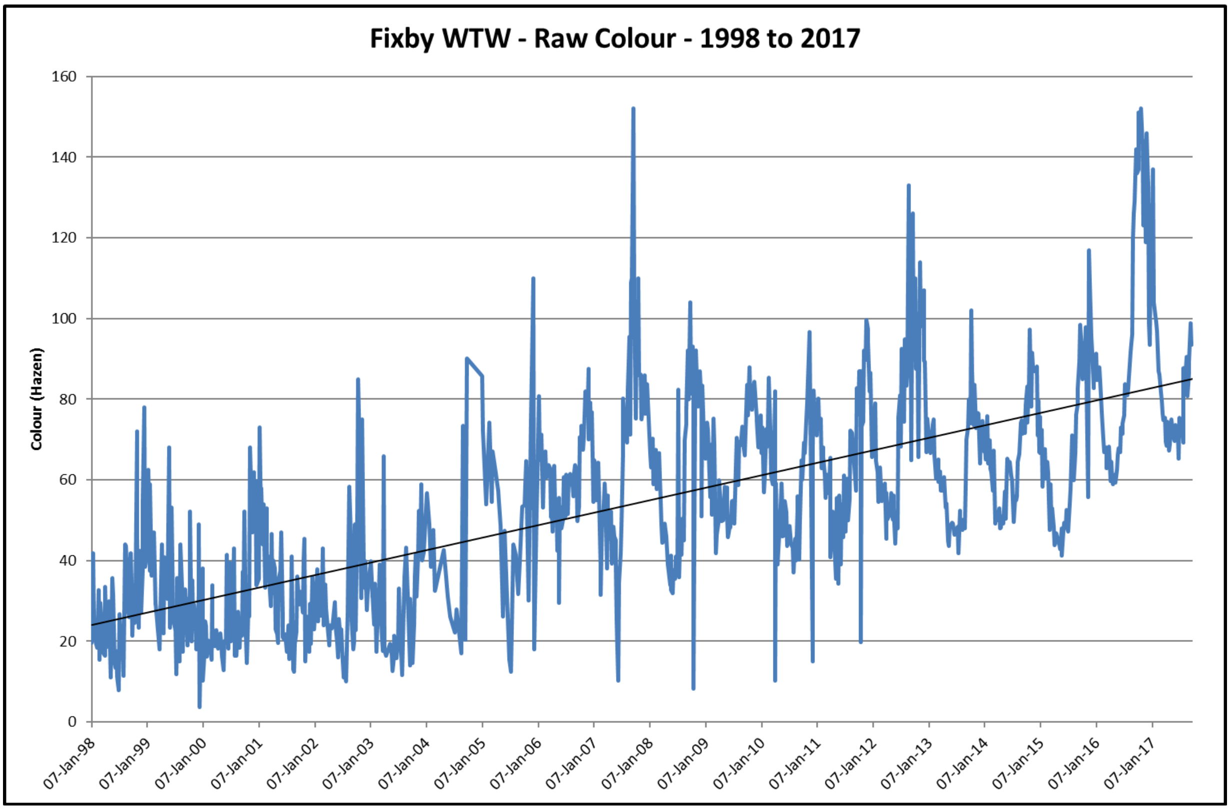


Figure. 14: Raw water colour data from Fixby sources.

Table 21:Zone THM's 2007 to 2017 RR coded samples only.

Zone	Year	THM Total (µg/l)			
		Total No of samples	Max	Min	Average
BRIGHOUSE 2004 WSZ	2007	9	64	39.7	50.678
	2008	8	58.9	27.7	41.913
	2009	8	71.2	25.1	43.900
	2010	8	54.9	25.6	38.913
	2011	8	52.5	29.8	40.838
	2012	8	66.2	25.7	39.850
	2013	8	52.61	18.5	34.453
	2014	8	54.5	25.4	39.155
	2015	8	54.98	26.83	41.735
	2016	8	56.94	21.93	40.444
	2017	4	54.46	32.83	41.900
WAKEFIELD CITY S 2008 WSZ	2007	12	64.2	28.5	42.150
	2008	7	58.6	29.7	37.243
	2009	6	47.3	1	35.533

	2010	9	54.8	28.8	36.711
	2011	8	68.8	19.3	38.013
	2012	8	57.7	27.1	39.975
	2013	8	58.99	22	33.110
	2014	8	62.77	27.31	39.953
	2015	8	62.43	31.91	41.509
	2016	8	66.17	27.68	37.128
	2017	4	64.09	32.64	45.888

Details of any existing contraventions of regulatory requirements.

The risks as identified in the Regulation 28 report for Fixby WTW are presented in table 22.

Table 22: Drinking Water Safety Planning (DWSP) risk assessment for Fixby WTW.

Intolerable Risk

There are no future or current intolerable risks identified in Fixby WTW.

Future Red Risk

Risk ID: 20709 (updated 08/11/2017) – Post risk score 23.
Fixby WTW - Failure to sufficiently treat raw water for colour and to prevent DBP formation.
Description - There is an increasing trend for colour at Fixby WTW.
Predicted Year – Estimate 2027 for colour
Effect Area – Water Quality
Risk – Probability = Medium, Severity = Very High
Data available – Historical water quality sample data, analysis of future trends.
16086 – DAF

Current Risks

Current Amber Risk

Risk ID: 16086 (updated 30/11/2016) – Post risk score 16.
Fixby WTW – Failure of DAF processes.
Description – Turbidity increases coming off the DAFs (scrapers).
Effect Area – Water Quality
Risk – Probability = Low, Severity = High

Details of any other data relevant to hazard identified

Table 23: A table identifying statistically significant trends in raw water colour.

	JAN 1998+							
	By MONTH				By YEAR			
Site	Max	Mean	Median	Min	Max	Mean	Median	Min
Fixby	2.488	2.59	2.614	2.75	2.093	2.682	2.68	2.429

	JAN 2004+							
	By MONTH				By YEAR			
Site	Max	Mean	Median	Min	Max	Mean	Median	Min
Fixby	1.22	1.448	1.378	1.629	0.265	1.566	0.93	3.446

KEY:	Highly sig (@1% level)	Sig (@ 5% level)	Non sig

Summary of consumer complaints. None

Details of any events that have occurred in the catchment, WTW.

Details of any existing control measures that might influence the values.

Current control measures – catchment

Currently included as part of the Moorlife 2020 plan, both repair and resilience work is being undertaken including grip blocking work and sphagnum planting in areas within Baitings reservoir catchment.

Details of monitoring control measure

The Company's operational monitoring programme includes weekly samples for colour, etc taken at the individual WTW inlets.

Reasons for the presence of the hazard

Leeds University have completed a report investigating the occurrence and future trends in raw water colour. The investigations concluded the following reasons for the presence of raw water colour.
Over the period 1987-2015, water colour increased significantly ($p<0.01$), by between 1.5 and 4.9 Hazen/year, at 10 of the 11 sites. In contrast, over the period 1998-2015, water colour only increased significantly ($p<0.05$), by between 0.5 and 1.4 Hazen/year, at 6 of the 14 sites. This shows that the greatest rise in water colour occurred between 1987 and 1998.

Water colour was suppressed at all sites during the drought of 1995 and for several years following the drought (1996 & 1997) before increasing to very high-water colour values in 1998. Although droughts will continue to have an impact on water colour in the future, it is unlikely to be as pronounced as that observed following the 1995 drought, which was a 1 in 200-year event and coincided with a period of rapid decline in sulphur deposition.
Using linear regression modelling where multiple drivers were considered together, the most successful models in predicting colour Z-score over the period 1987-2015 were those that included SO_2 emissions and summer rainfall; explaining 88-97% ($p<0.001$) of the long-term trend in colour. Summer rainfall and SO_2 emissions were also successful, but to a lesser extent, in explaining colour variation over the period 1998-2015 at most sites (r^2= 71-96%, $p<0.001$ at 5 sites).

Both models (statistical and processes) show that the biggest increase in DOC/water colour was observed in the 1990s, as a result of declining SO_4 deposition which led to an increase in soil pH and therefore an increase in DOC solubility. Both models suggest that DOC/water colour (annual and monthly mean concentrations) will be similar in 2030 as they have been in the period 2010-2015, and that in the future climate change, in particular wet summers, will have a bigger impact in controlling DOC/water colour.

Outline Risk characterisation:

Stage 3 – Control Measures Required

Provide details of short, medium and long-term control measures i.e.

Details of short term actions currently in place

Catchment Inspections, sampling and turnout facilities

Details of mid to long terms control measures

In addition to the catchment restoration completed in AMP5, further resilience work is planned for AMP7 for Baitings catchment to include Sphagnum planting, flailing, Removal of fence and gully blocking. In addition, in Ringstone catchwater and Boothwood catchments sphagnum planting is to be completed.

Several catchments feeding Fixby WTW have been included in the Water Industry National Environment Programme (WINEP) to fund further repair and resilience activities. The action plan is to complete resilience work on Rishworth Moor, Soyland Moor and Moss Moor include vegetation diversification and inoculation with sphagnum. This may also include increasing dam heights in gullies where repair activity has filled them up to the next level.

Table 24: Catchments submitted into WINEP for Fixby WTW.

Driver Description	WINEPID	Function	RBD	Area	Water Company	Unique ID	Scheme Name	Waterbody	Waterbody ID	Water Body Type(s)	WFD Catchment	Driver Code
Drinking Water Protected Areas	YOR00188	WQ	Humber	Yorkshire	Yorkshire Water Service Ltd	7YW200132	Rishworth / Green Withens/ Boothwood	Booth Dean Clough from Source to River Ryburn	GB104027062520	River	Calder Middle	DrWPA_ND
Drinking Water Protected Areas	YOR00189	WQ	Humber	Yorkshire	Yorkshire Water Service Ltd	7YW200133	Baitings	Ryburn from Source to Booth Dean Clough	GB104027062540	River	Calder Middle	DrWPA_ND

Options the company has considered e.g. catchment management

The Company has been undertaking catchment management in the Baitings and Boothwood areas to begin the process of repairing the damaged peatland which dominates the catchment; however, this activity is likely to take between 10-20 years to stabilise colour levels from the impounding reservoirs, and longer to begin to improve them. Given the long-term and uncertain nature of the restoration of peatland it is unlikely that in the short to medium term this approach can be relied upon to deliver and sustain compliance for DBPs.

Catchment Management will be pursued in parallel with the proposed engineered solution as a means of ensuring that this is sustainable for the long-term, and over time the additional operating costs of the treatment solution can be reduced.

Capital costs and net additional; operating costs

Table 25: Fixby WTW scheme costs.

Site	Capex (£million)	Opex per annum (£million)
Fixby WTW	£ 5.6	£ 0.04

Full details of how the company intends to assess and measure the benefits delivered

Colour/DBPs

The Company will use 3 main techniques to demonstrate the benefits to water quality of the proposed solutions:

1. Continuation of the long-term monitoring of raw water quality for relevant parameters – to track the progress of catchment management and corroborate on line raw water monitoring. We are about to start work on an R&D project to identify potential solutions for real-time monitoring in locations where there is no power and communication infrastructure.
2. Use of on-line UV254 analysers (or similar) to track the DOC of incoming raw water, post MIEX, and blended raw waters – this will provide direct evidence of the amount of DOC being removed prior to coagulant dosing.
3. Structured network sampling for DBPs – currently planned to be THMs and HAAs – to include WTW outlet, SRE outlets, and customer tap samples to encompass the range of travel times within the system supplied by Fixby WTW.

Oldfield WTW

Scheme details

Water Company:

Yorkshire Water Services Limited

Date of submission:

31st December 2017

Name of water Treatment Works/ Distribution System/ Service Reservoir/ Other asset:

Oldfield WTW (T4695450)

Water quality hazard/ drivers identified:

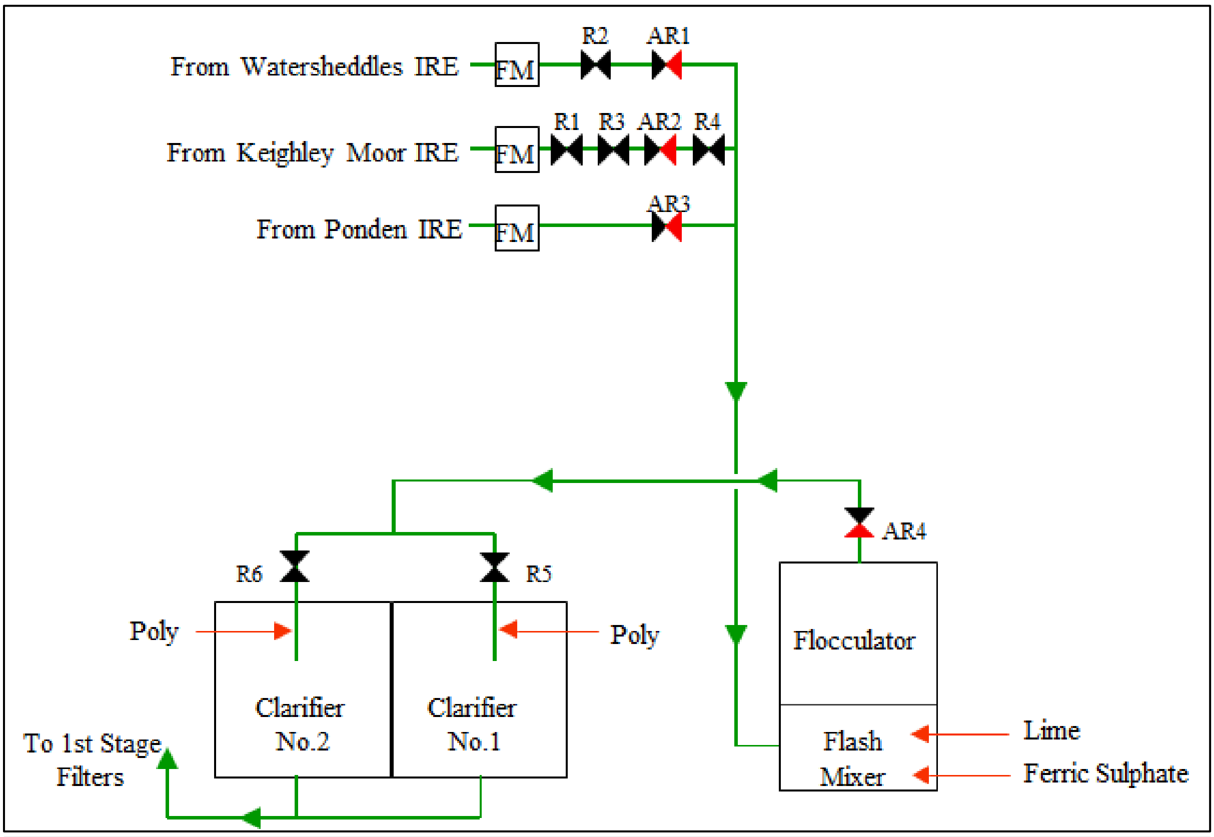
Raw water colour deterioration as a surrogate for disinfection by products (DBPs) generation risk and DBP minimisation.

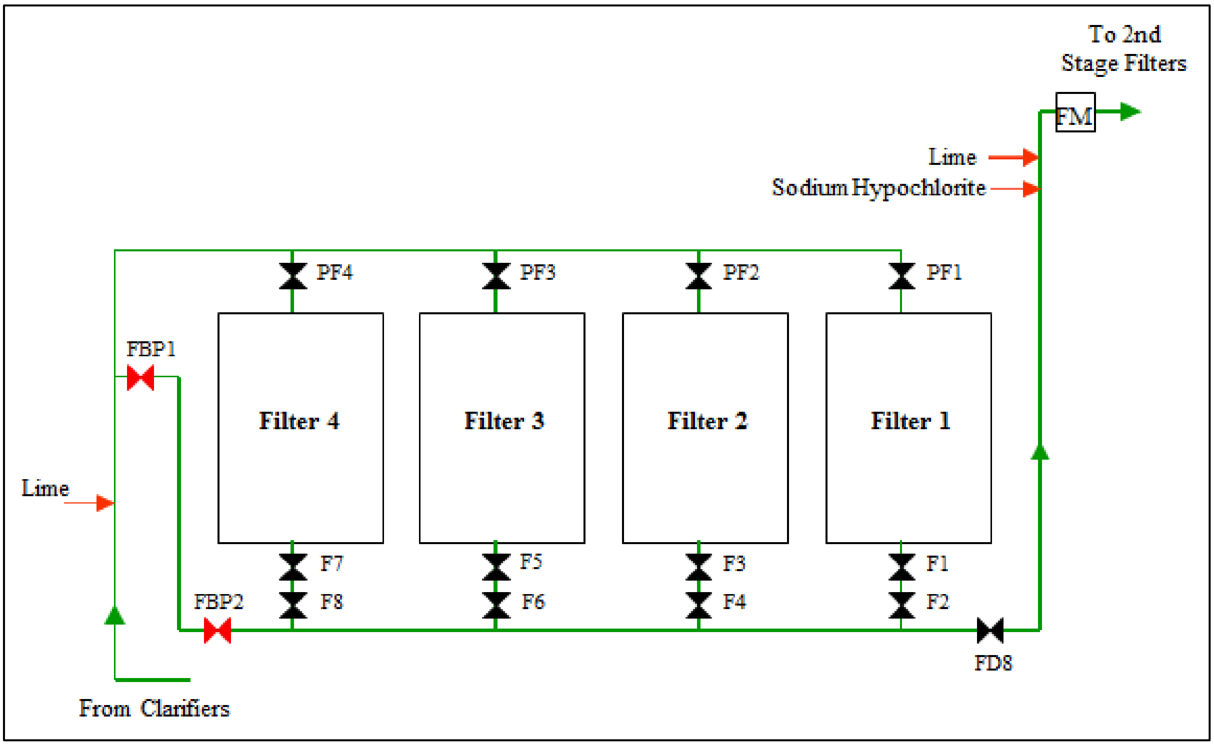
Reference to outcome in company's long-term strategy:

Enhanced Drinking Water Quality

Stage Once – Details of water treatment works and associated supply system

Provide supply arrangements and treatment works details:





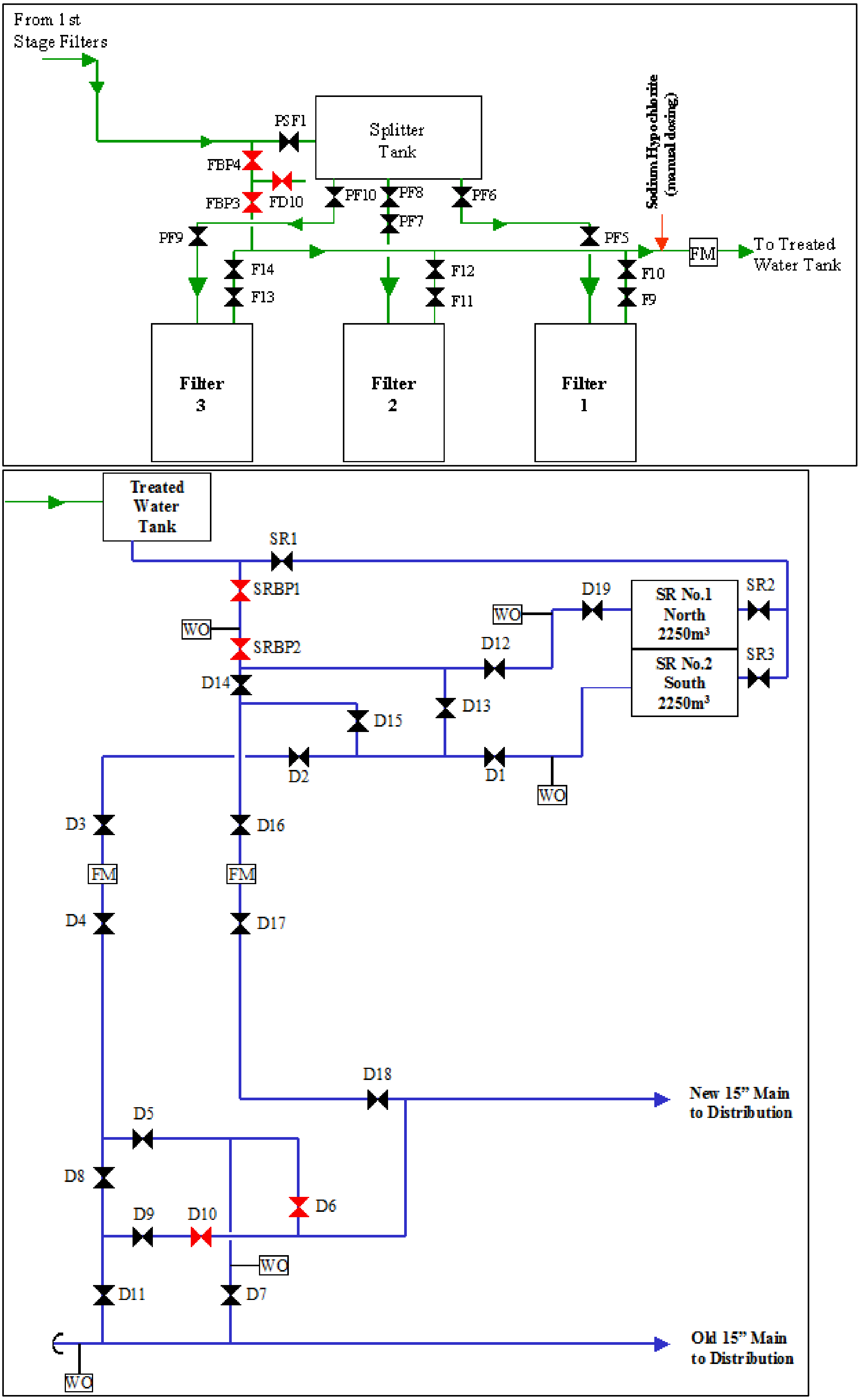


Figure. 15: Site schematic for Oldfield WTW.

Table 26: Two tables illustrating the design and current flow capacities of Oldfield WTW.

Design Flows (Ml/d)	Minimum	Maximum
Inlet Flow	4	10
Outlet Flow	-	10

Current Flows (Ml/d)	Minimum	Average	Maximum
Inlet Flow	4	6.9	9.2
Outlet Flow	4	6.5	9.6

Sources of raw water

Oldfield WTW is supplied from three impounding reservoirs. Water from Keighley Moor IRE is fed directly to Oldfield WTW via a pipeline. Water from Watersheddles IRE is fed to Oldfield WTW. Any overflow or scour discharges run into the River Worth which in turn flows into Ponden IRE. Ponden pumping station would only be operated if the supply to Oldfield WTW from Watersheddles IRE was unavailable.

Table 27: Oldfield WTW - raw water sources.

Source Name	Source of Water
Keighley Moor IRE	Impounding reservoir
Watersheddles IRE	Impounding reservoir
Ponden IRE	Impounding reservoir

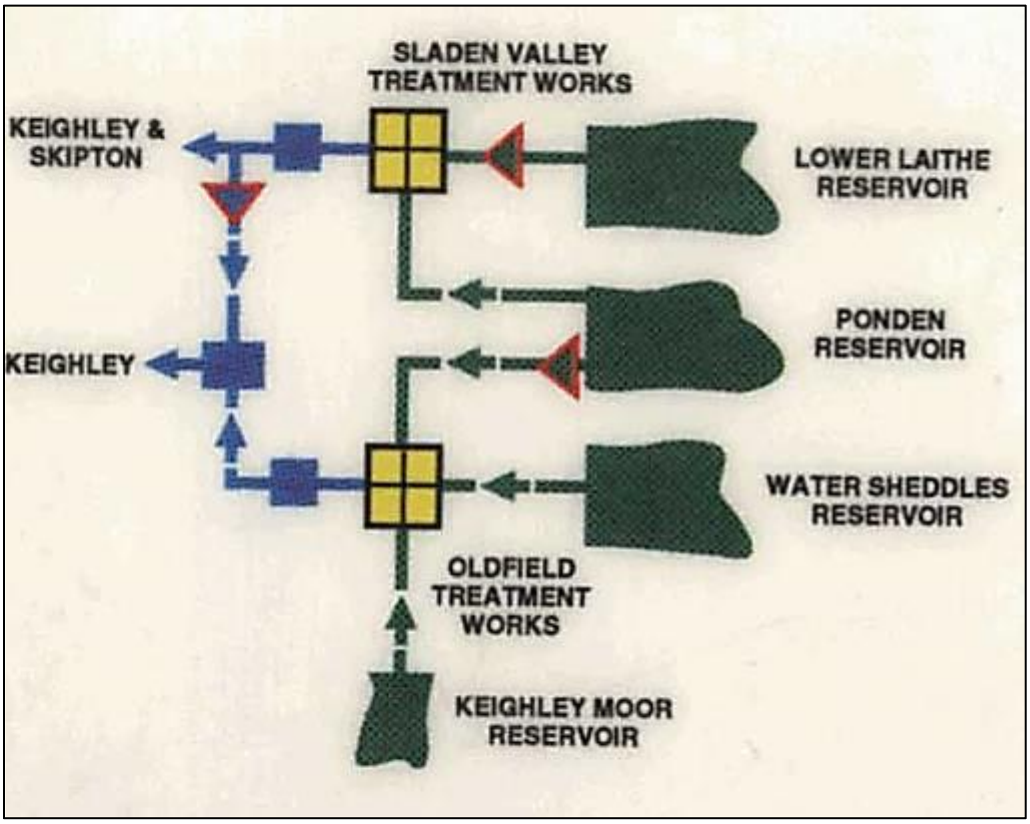


Figure. 16: Oldfield WTW and Sladen Valley WTW raw water supply system.

Treatment process

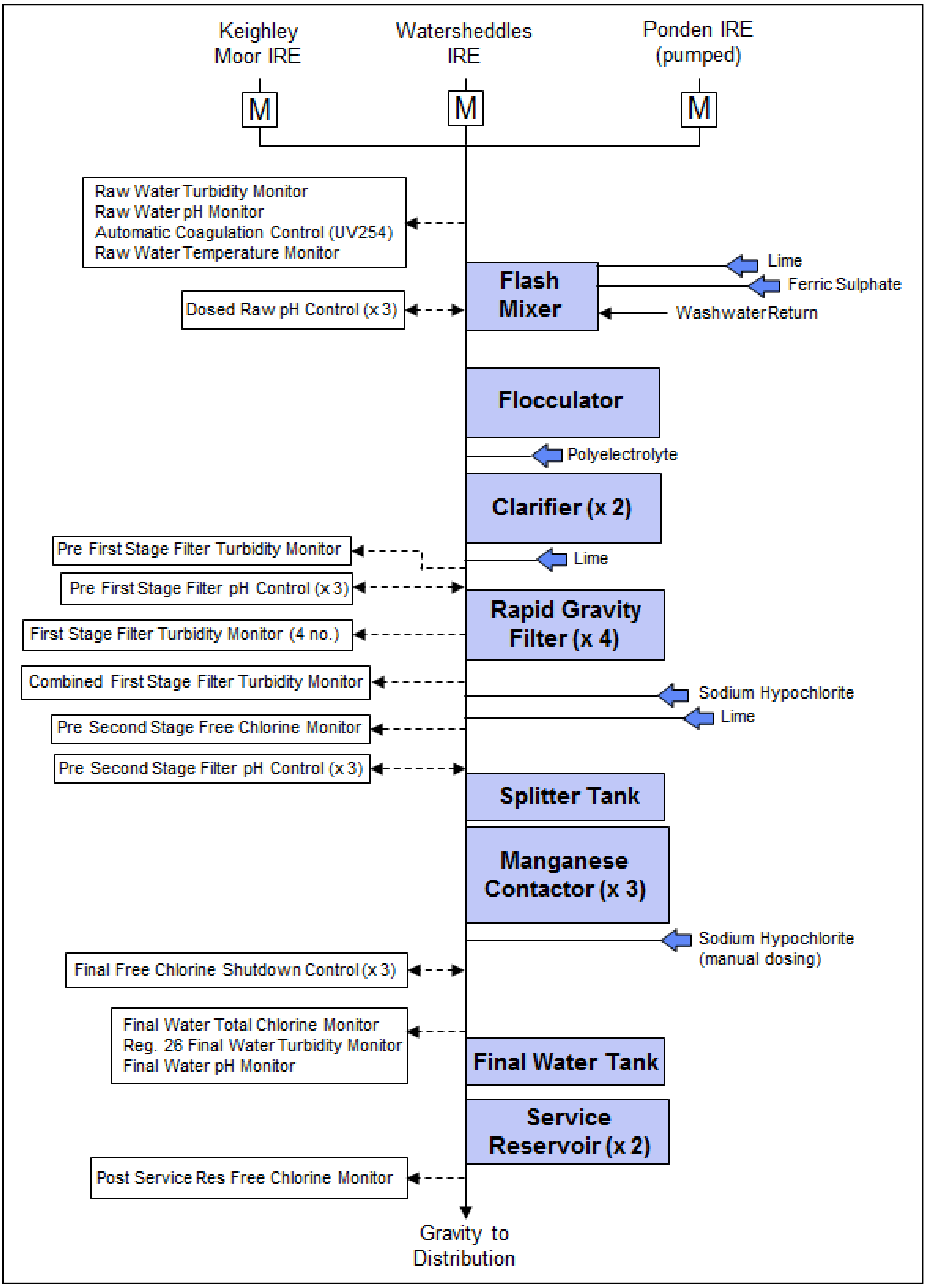


Figure. 17: Process schematic for Oldfield WTW.

Raw water for treatment at Oldfield can be supplied from a combination of three sources, Keighley Moor, Watersheddles and Ponden (pumped). Three inlets for the above sources enter a common main, where raw sample points for each source are located, then the mixed water enters the flash mixer.

Ferric sulphate and lime are injected past the raw sample points as the mixed water enters the flash mixer. From the flash mixer, dosed water enters a flocculator. The dosed water is then gravity fed via a pipeline to two clarifiers. Prior to the dosed water entering the clarifiers, a dose of polyelectrolyte is injected into each inlet pipe. Within each of the clarifiers there are two sludge cones which bleed floc to a sludge holding tank, then to sewer.

The clarified water is then dosed with lime before going on to four first stage rapid gravity filters. After first stage filtration, water is fed towards a splitter tank that feeds water to three second stage rapid gravity filters. Before entering this unit, a dose of sodium hypochlorite and lime is injected. MSP is also injected at this stage into the flash mixer. Water from the splitter tank is fed into the second stage filters. After second stage filtration, water is fed into a final water tank.

The final water tank supplies water (pumped) for filter washing and service water (pumped), as well as acting as a contact tank. Water is then gravity fed to the two clean water tanks and then into distribution.

Service reservoirs

Treated water leaves the clean water tanks by gravity to feed Oxenhope, Haworth, Oakworth and Hainworth. In addition, treated water also flows by gravity to Blackhill and Whitelane service reservoirs to supply parts of Keighley.

Table 28: A table showing the water supply zone (WSZs) fed from Oldfield WTW.

WTW	Water Supply Zone	%WTW Supply	WSZ Ml/d	WSZ Population
Oldfield	Keighley 2004	100.00%	5.68	73481

Stage Two – Hazard identification and Risk Characterisation

Provide details of methodology used to identify hazards i.e. historic data, events/ incidents including near miss situations, operator knowledge, modelling and site visits/ technical audits:

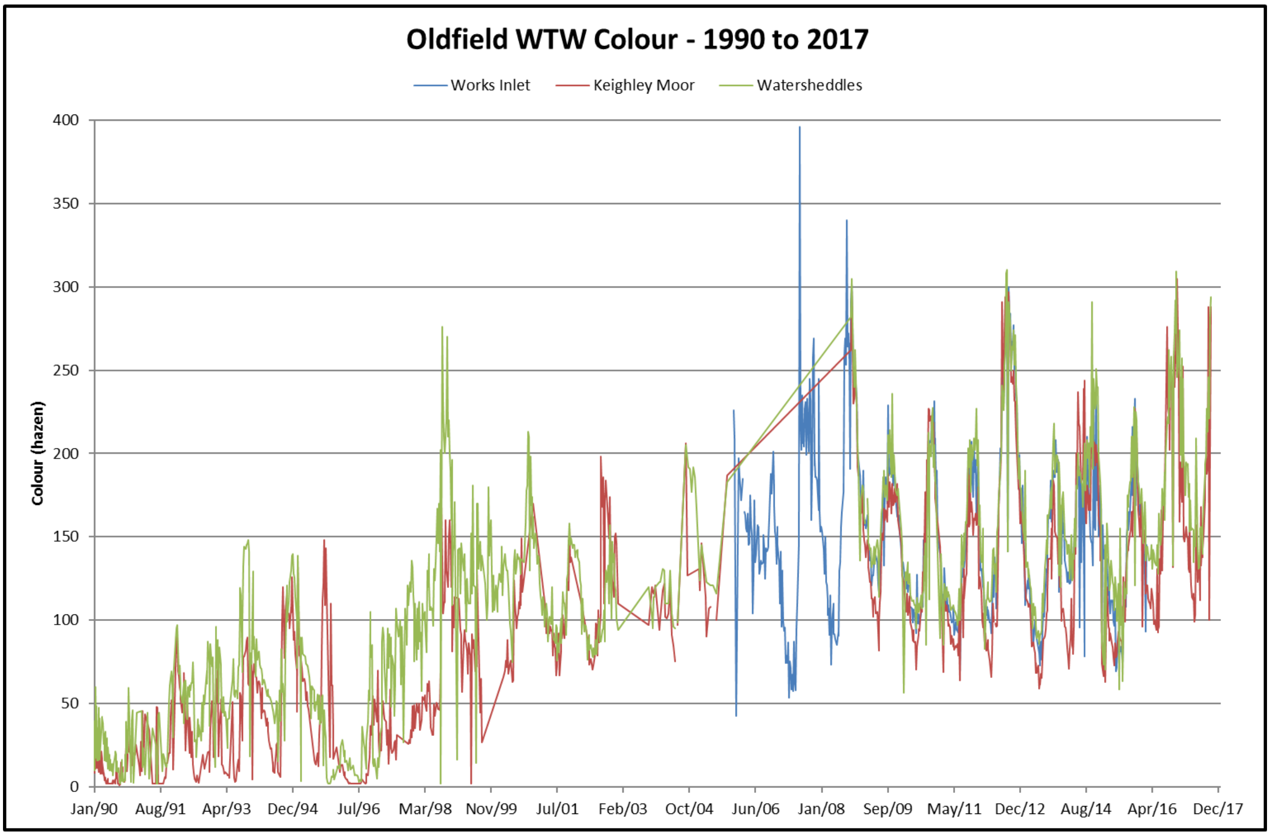


Figure. 18: Chart displaying historic to present raw water colour trend.

Table 29: WSZ THM's for Oldfield and Sladen Valley WTW 2010 to 2017

WSZ	Year	No of Samples	Average
	2010	8	48.78
	2011	8	47.34
	2012	8	50.03
	2013	8	41.87
	2014	8	44.80
	2015	8	47.74
KEIGHLEY 2004 WSZ	2016	8	51.42

The risks as identified in the Regulation 28 report for Oldfield WTW are presented in table 30.

Table 30:Drinking Water Safety Planning (DWSP) risk assessment for Oldfield WTW.

Intolerable Risk
<u>Current Intolerable Risks</u> There are no current intolerable risks identified in Oldfield WTW.
<u>Future Intolerable Risks</u> There are no future intolerable risks identified in Oldfield WTW.
<u>Future Red Risk</u> **Risk ID:** 17466 (10/10/2017) – Post risk score 24. **Oldfield WTW** - Failure to sufficiently treat raw water for colour and to prevent DBP formation. **Description** - There is an increasing trend for colour at Oldfield WTW - Over the longer term it is likely that DBP optimisation by reducing flow and support from other WTW is unlikely to be sustainable. Future intolerable risk identified. **Predicted Year** – 2020 **Effect Area** – Water Quality **Risk** – Probability = High, Severity = Very High **Data available** – Historical water quality sample data, analysis of future trends. **Risk ID:** 12553 (updated 10/10/2017) – Post risk score – 23. **Oldfield WTW –** Failure of clarifier processes. **Description** - Tanks are Asset Life Expired - potential structural issues, this risk relates to failure of the building structure. **Predicted Year -** Now **Effect Area** – Clarification **Risk -** Probability = Medium, Severity = Very High **Data available –** Asset inspections **Risk ID:** 12622 (updated 10/10/2017) – Post risk score – 23. **Oldfield WTW –** Failure of asset due to condition or design. **Description** - Asset Life Expired. RGF's are within the same building as the clarifiers. This risk relates to failure of the building structure. **Predicted Year -** Now **Effect Area** – Clarification **Risk -** Probability = Medium, Severity = Very High **Data available –** Asset inspections
<u>Current Amber Risk</u> **Risk ID:** 19834 (updated 10/10/2017) – Post risk score – 20. **Oldfield WTW –** Failure of asset due to condition or design. **Description** – RGF tanks are Asset Life Expired. **Effect Area** – Filtration **Risk -** Probability = Low, Severity = Very High **Data available –** Asset inspections **Risk ID:** 17465 (updated 10/10/2017) – Post risk score – 20. **Oldfield WTW –** Failure to sufficiently treat raw water for colour and to prevent DBP formation. **Description** – The raw water entering Oldfield WTW is very high in colour peaking at over 350Hazen from the Watersheddles source in the past.

Effect Area – Water Quality
Risk - Probability = Low, Severity = Very High
Data available – Water quality data.

Risk ID: 12626 (updated 10/10/2017) – Post risk score – 19.
Oldfield WTW – Failure of second stage filtration – manganese contactors.
Description – Asset Life Expired - but works well. Asset is not designed to engineering standards.
Effect Area – Manganese Removal
Risk - Probability = Medium, Severity = High

Evidence of likely to contravene any regulatory requirements.

Details of any other data relevant to hazard identified

Table 31: A table identifying statistically significant trends in raw water colour.

	1987 - 2015 Leeds	1998 to 2015 Leeds	1987 - 2015 Leeds			1998 to 2015 Leeds		
	By Month	By Month	By Year			By Year		
Site	Median	Median	Max	Mean	Min	Max	Mean	Min
Oldfield - KM	4.94	1.44	7.24	5.59	1.63	3.929	3.41	3.41
Oldfield - WS	4.72	0.99	6.63	5.1	3.51	4.039	1.73	3.06

KEY:	Highly sig (@1% level)	Sig (@ 5% level)	Non sig

2010 to 2015 Catchment Schemes have not yet delivered improvement in Colour DOC. When long term data sets are considered there are highly significant and large increases in colour Max, Mean and Min. Data from 1998, shows a significant upward trend on yearly Mean and Min colour trends.

Details of any events that have occurred in the catchment, WTW. None

Existing control measures – catchment

The catchment management work undertaken by the Company as part of this Undertaking took place solely on Keighley Moor.

The work at Keighley Moor included the following activities below;

- gully blocking
- gully reprofiling
- vegetation management, such as control of heather cutting and burning
- stabilising and raising the hydrology of the peat
- creation of pools to encourage the growth of peat-forming species, such as sphagnum moss

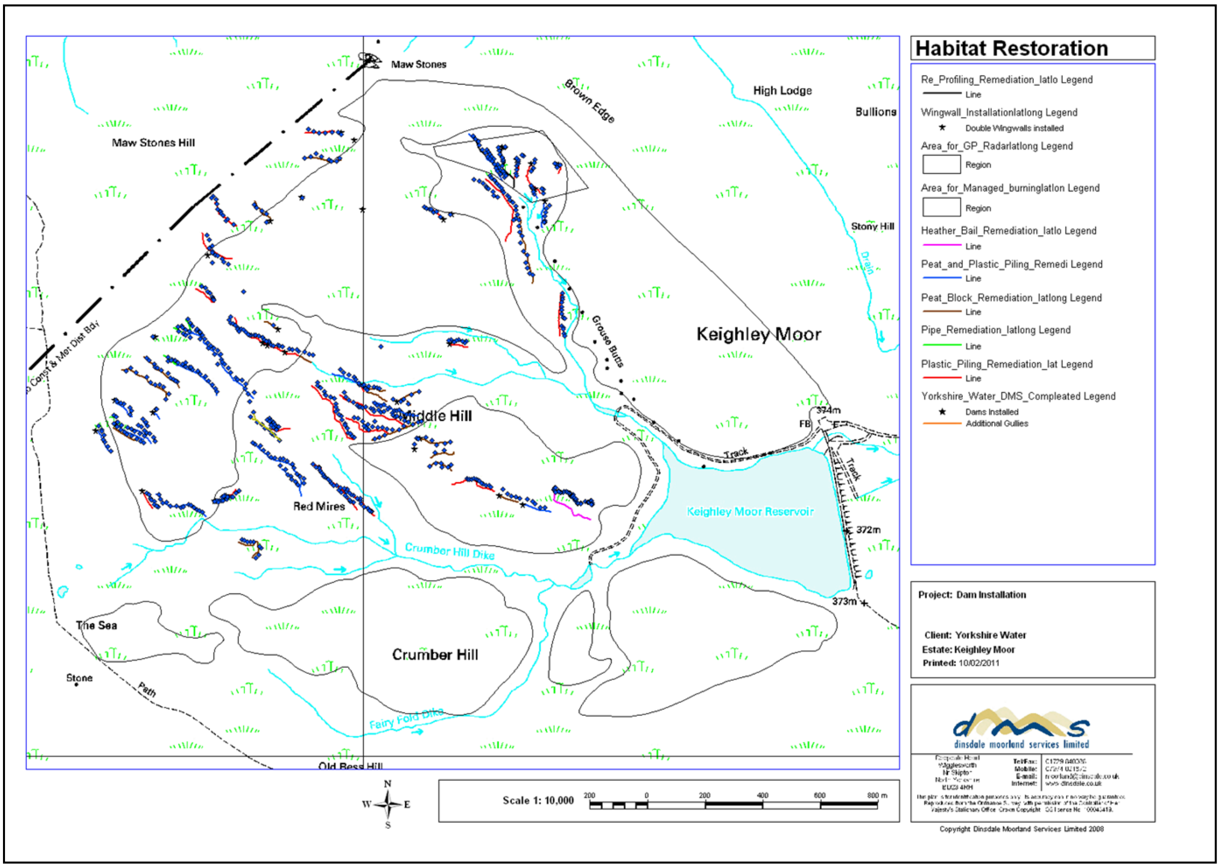


Figure. 19: Restoration work completed on Keighley Moor reservoir catchment.

Details of monitoring control measure

The Company's operational monitoring programme includes weekly samples for colour, etc. taken at the individual WTW inlets.

Stream sampling of the Keighley Moor catchment has occurred since 2008 and included 10 grab sample points on main tributaries and the inputs to the reservoir. After 18/02/2009 three further locations were added. The sampling frequency initially was every 2 weeks but was reduced to every 3 weeks between the start of November and end of March as requested by the gamekeeper from November 2012. After July 2015, the sampling frequency changed to every 3 weeks throughout the year. In addition to grab samples autosamplers collect stream water during high flow events.

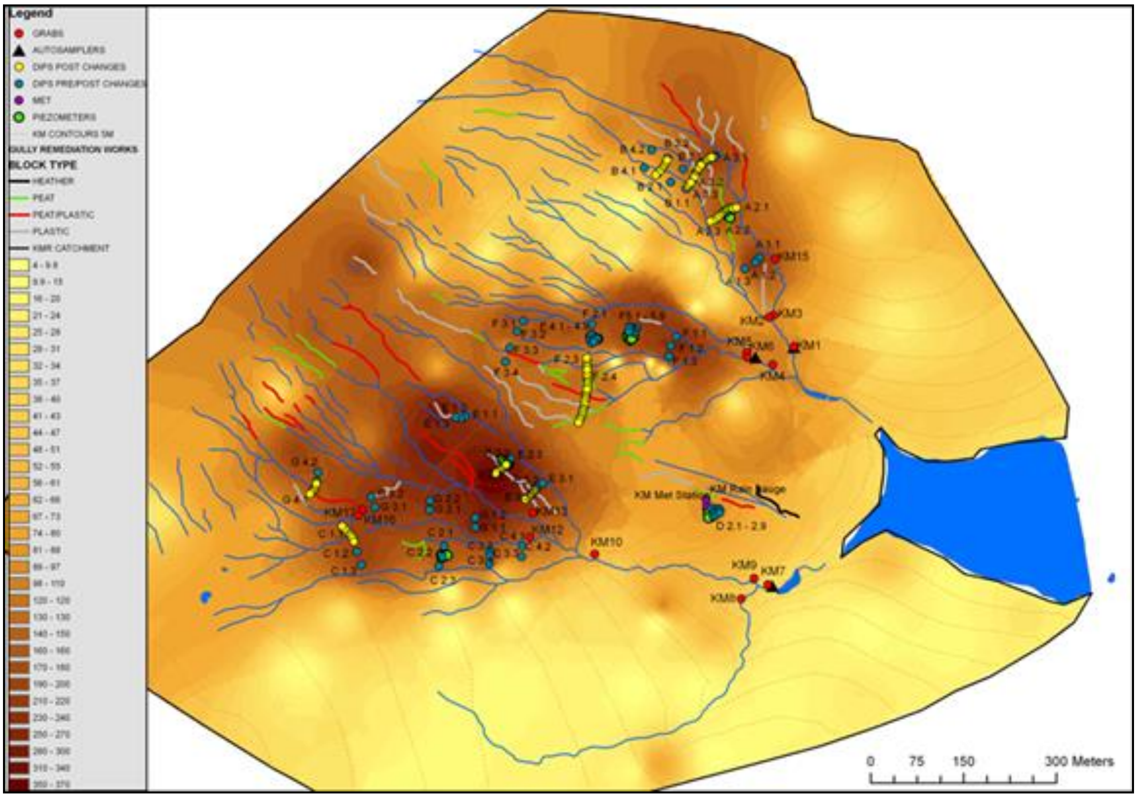


Figure. 20: Map detailing monitoring locations and peat depths on Keighley Moor catchment.

Reasons for the presence of the hazard

Leeds University have completed a report investigating the occurrence and future trends in raw water colour. The investigations concluded the following reasons for the presence of raw water colour.

Over the period 1987-2015, water colour increased significantly ($p<0.01$), by between 1.5 and 4.9 Hazen/year, at 10 of the 11 sites. In contrast, over the period 1998-2015, water colour only increased significantly ($p<0.05$), by between 0.5 and 1.4 Hazen/year, at 6 of the 14 sites. This shows that the greatest rise in water colour occurred between 1987 and 1998.

Water colour was suppressed at all sites during the drought of 1995 and for several years following the drought (1996 & 1997) before increasing to very high-water colour values in 1998. Although droughts will continue to have an impact on water colour in the future, it is unlikely to be as pronounced as that observed following the 1995 drought, which was a 1 in 200-year event and coincided with a period of rapid decline in sulphur deposition.

Using linear regression modelling where multiple drivers were considered together, the most successful models in predicting colour Z-score over the period 1987-2015 were those that included SO_2 emissions and summer rainfall; explaining 88-97% ($p<0.001$) of the long-term trend in colour. Summer rainfall and SO_2 emissions were also successful, but to a lesser extent, in explaining colour variation over the period 1998-2015 at most sites (r^2= 71-96%, $p<0.001$ at 5 sites).

Both models (statistical and processes) show that the biggest increase in DOC/water colour was observed in the 1990s, as a result of declining SO_4 deposition which led to an increase in soil pH and therefore an increase in DOC solubility. Both models suggest that DOC/water colour (annual and monthly mean concentrations) will be similar in 2030 as they have been in the period 2010-2015, and that in the future climate change, in particular wet summers, will have a bigger impact in controlling DOC/water colour.

Outline Risk characterisation:

Stage 3 – Control Measures Required

Provide details of short, medium and long-term control measures i.e.

Details of short term actions currently in place.

Catchment Inspections and turnout

Details of mid to long terms control measures

Keighley Moor and Watersheddles catchments have been included in the Water Industry National Environment Programme (WINEP) to fund further repair and resilience activities. The action plan is to complete resilience work on Keighley Moor and Watersheddles will include vegetation diversification and inoculation with sphagnum. This may also include increasing dam heights in gullies where repair activity has filled them up to the next level.
The Company has continued to influence other activity that is being planned on nearby catchments – namely the HLS work being proposed by NE. Close liaison and directing future work towards higher-risk areas will ensure that best benefits are obtained from the NE work, which is planned for a 10-year period and covers the whole of the Walshaw estate (which includes the Watersheddles catchment). Figure 22 below shows an example of the type of work being planned by Natural England in a neighbouring area, and we anticipate similar being undertaken in the Watersheddles area later in the programme.

Figure. 21: Catchments submitted into WINEP for Oldfield WTW.

Driver Description	WINEPID	Function	RBD	Area	Water Company	Unique ID	Scheme Name	Waterbody	Waterbody ID	Water Body Type(s)	WFD Catchment	Driver Code
Drinking Water Protected Areas	YOR00154	WQ	Humber	Yorkshire	Yorkshire Water Service Ltd	7YW200098	Oldfield - Keighly Moor	North Beck from Source to River Worth	GB1040270 64230	River	Aire Middle	DrWPA_ND
Drinking Water Protected Areas	YOR00155	WQ	Humber	Yorkshire	Yorkshire Water Service Ltd	7YW200099	Oldfield - Watershedd les	Worth from Source to Bridgehouse Beck	GB1040270 64210	River	Aire Middle	DrWPA_ND

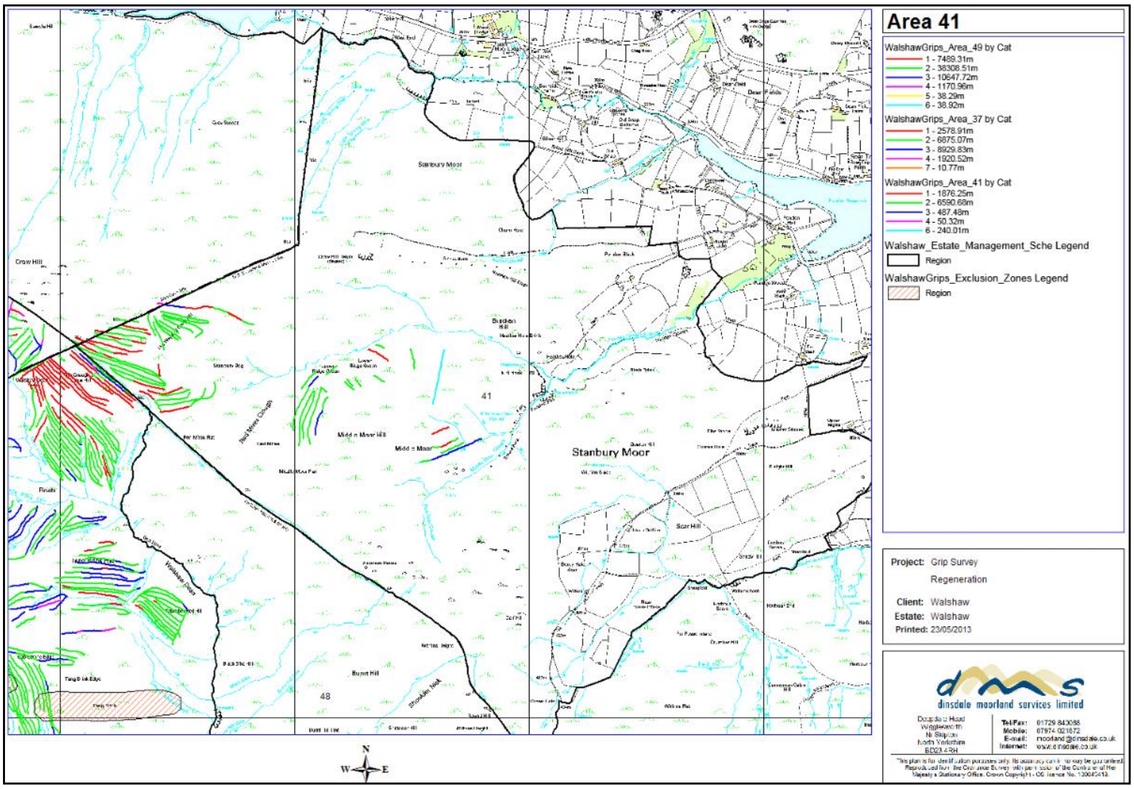


Figure. 22: Example of NE work near to the Oldfield raw water sources catchments.

Options the company has considered eg catchment management

The Company has been undertaking catchment management in the Keighley Moor area to begin the process of repairing the damaged peatland which dominates the catchment; however, this activity is likely to take between 10-20 years to stabilise colour levels from the impounding reservoirs, and longer to begin to improve them. Given the long-term and uncertain nature of the restoration of peatland it is unlikely that in the short to medium term this approach can be relied upon to deliver and sustain compliance for DBPs.

Catchment Management will be pursued in parallel with the proposed engineered solution as a means of ensuring that this is sustainable for the long-term, and over time the additional operating costs of the treatment solution can be reduced.

Table 32: Oldfield WTW scheme costs.

Site	Capex (£million)	Opex per annum (£million)
Oldfield WTW	£ 6.1	£ 0.1

Full details of how the company intends to assess and measure the benefits delivered

Colour/DBPs

The Company will use 3 main techniques to demonstrate the benefits to water quality of the proposed solutions:

1. Continuation of the long-term monitoring of raw water quality for relevant parameters – to track the progress of catchment management and corroborate on line raw water monitoring. We are about to start work on an R&D project to identify potential solutions for real-time monitoring in locations where there is no power and communication infrastructure.
2. Use of on-line UV254 analysers (or similar) to track the DOC of incoming raw water, post MIEX, and blended raw waters – this will provide direct evidence of the amount of DOC being removed prior to coagulant dosing.

Structured network sampling for DBPs – currently planned to be THMs and HAAs – to include WTW outlet, SRE outlets, and customer tap samples to encompass the range of travel times within the system supplied by Oldfield WTW.

Sladen Valley

Scheme details

Water Company:

Yorkshire Water Services Limited

Date of submission:

31st December 2017

Name of water Treatment Works/ Distribution System/ Service Reservoir/ Other asset:

Sladen Valley No' 2 WTW (T4696770).

Water quality hazard/ drivers identified:

Raw water colour deterioration as a surrogate for disinfection by products (DBPs) generation risk and DBP minimisation.

Reference to outcome in company's long-term strategy:

Enhanced Drinking Water Quality

Stage One – Details of water treatment works and associated supply system

Provide supply arrangements and treatment works details:

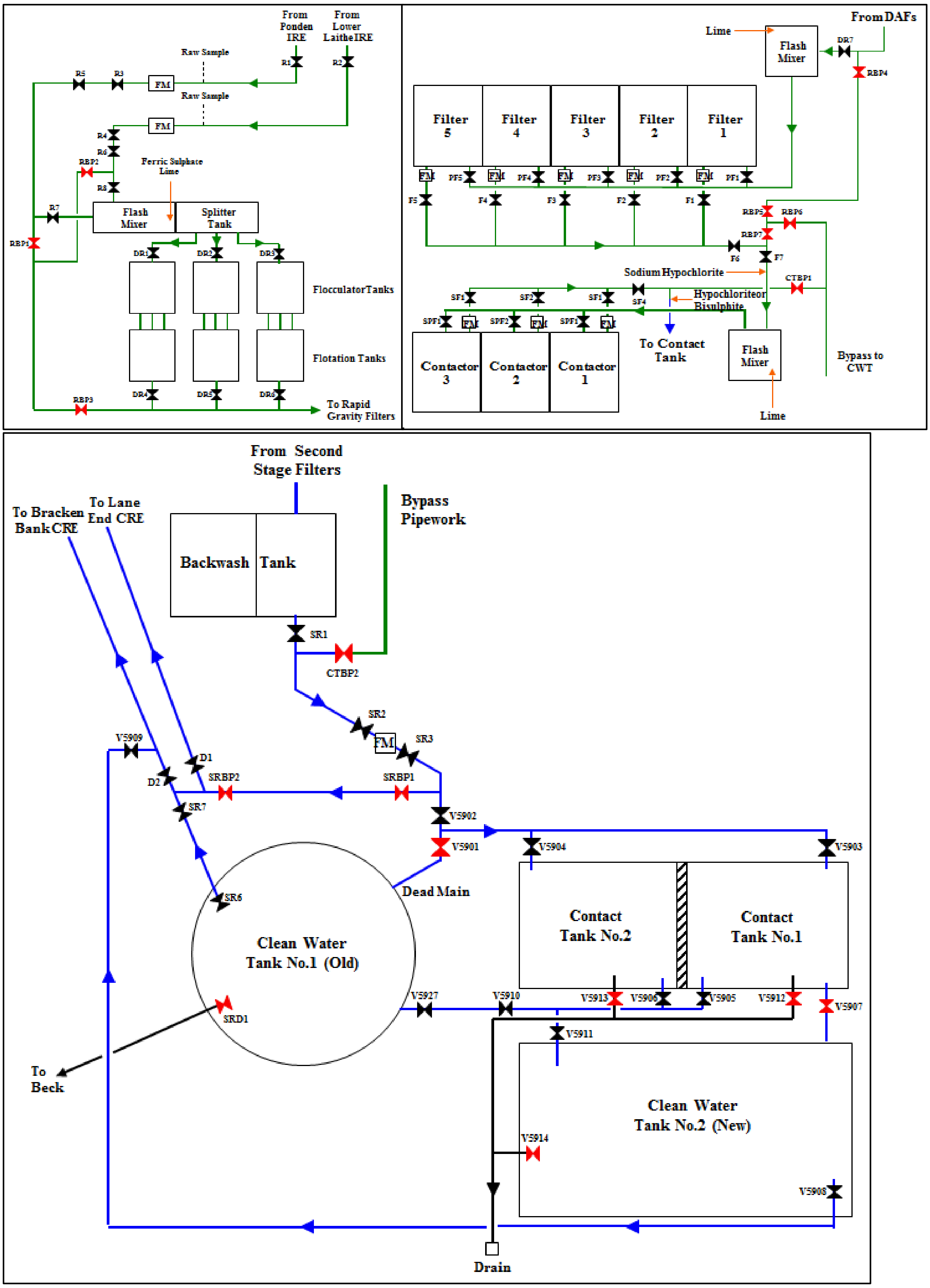


Figure. 23: Site schematic for Sladen Valley WTW.

Table 33: Two tables illustrating the design and current flow capacities of Sladen Valley WTW.

Design Flows (Ml/d)	Minimum	Maximum
Inlet Flow	-	-
Outlet Flow	-	10

Current Flows (Ml/d)	Minimum	Average	Maximum
Inlet Flow	4.5	8	12.5
Outlet Flow	4.5	7.5	11.8

Sources of raw water

Sladen Valley WTW is supplied from two impounding reservoirs. Both sources are fed directly to the WTW via individual direct pipelines.

Table 34: Sladen Valley WTW - raw water sources.

Source Name	Source of Water
Lower Laithe IRE	Impounding reservoir
Ponden IRE	Impounding reservoir

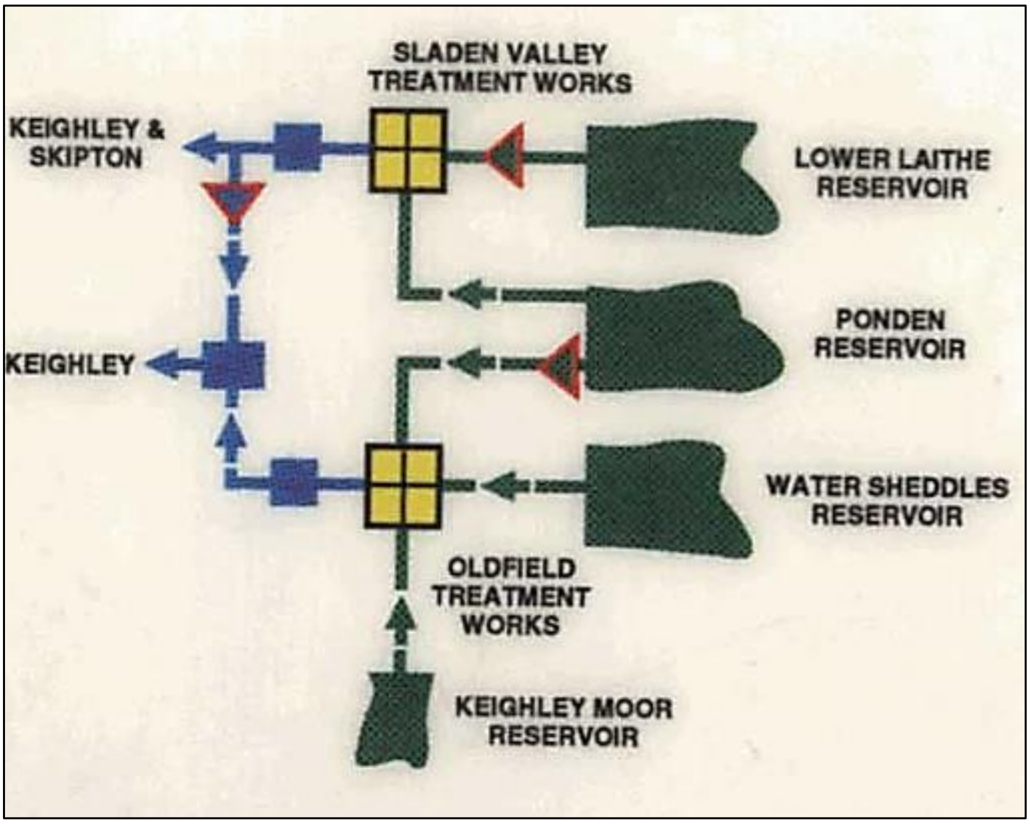


Figure. 24: Oldfield WTW and Sladen Valley WTW raw water supply system.

Treatment process

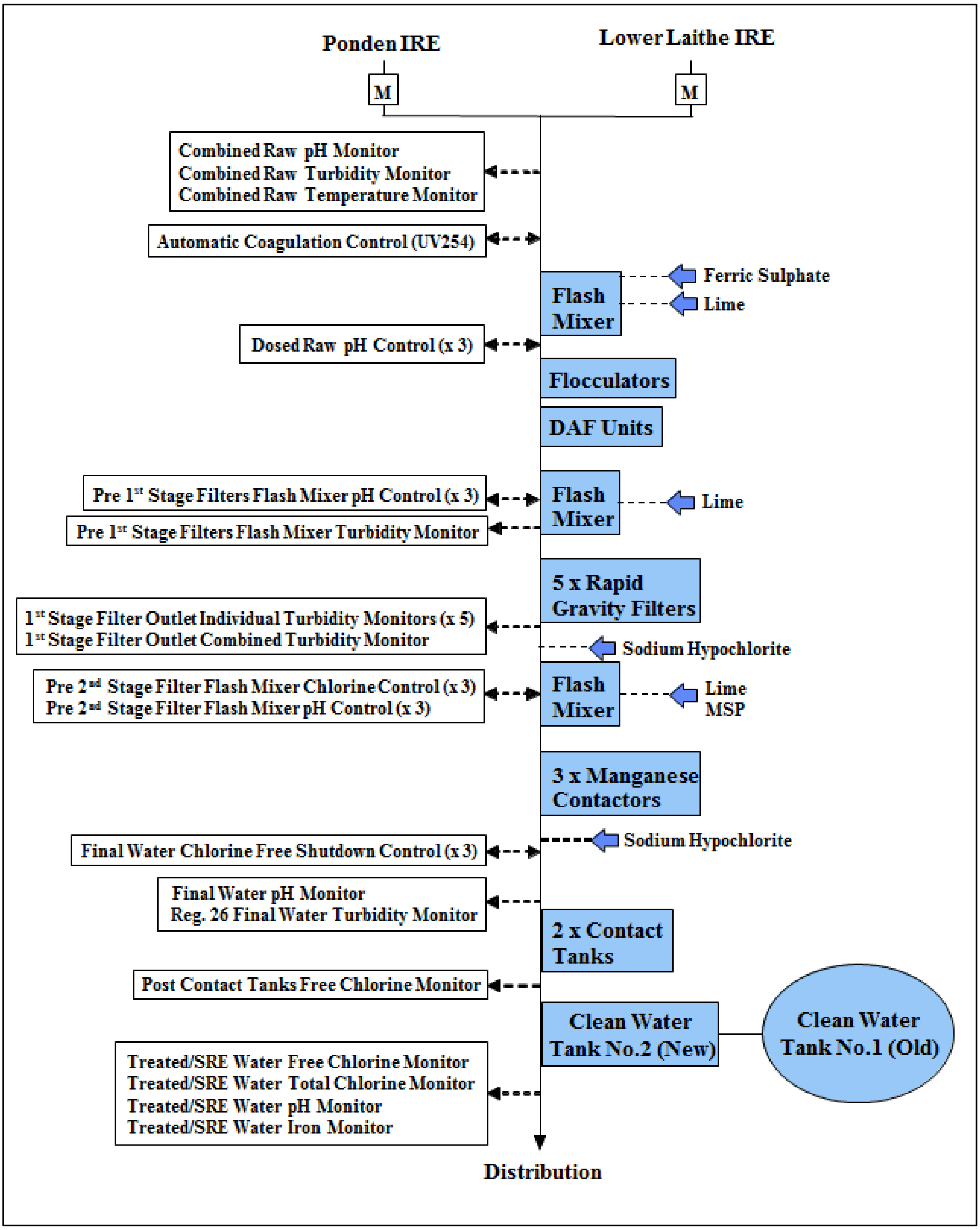


Figure. 25: Process schematic for Sladen Valley WTW.

Two raw water inlet mains supply water from Lower Laithe and Ponden. The two raw mains then enter the dosed raw flash mixer. As raw water enters the dosed raw flash mixer, a dose of ferric sulphate and lime is injected. The ferric sulphate dosing system runs on flow paced dosing or ACC control.

From the dosed raw flash mixer, water flows into flow splitting tank 1 which directs the water flow into three flocculation tanks. From the three flocculation tanks, water flows into three flotation tanks. Each flotation tank receives aerated water from the water aeration system. The aeration system comprises two saturation vessels which receive water from either the flotation tank outlet (strained) or after the first stage filters and air from the compressed air system. A timer controls desludging of the flotation units, sludge flows to the sludge holding tank.

Water from the flotation units flows into the pre 1st stage filter flash mixer, where it is given a dose of lime. Water flows from the pre 1st stage filter flash mixer into five first stage rapid gravity filters. Filter outlet flow is via the individual outlet valves on each filter which are controlled by the pre 1st stage filter flash mixer flow control unit. After the filtered water passes through these valves there is an emergency shut down valve (linked to the emergency shut down system). Water is then dosed with chlorine from the O.S.E.C. system. Water flows into the pre 2nd stage filter flash mixer, lime is dosed into the pre 2nd stage filter flash mixer. MSP is also dosed in flash mixer 3 prior to second stage filtration.

Water then flows to three second stage manganese contactors. Backwashing of the filters is automatic, controlled by a program in the PLC. Filter outlet flow is via the individual outlet valves on each filter which are controlled by the pre 2nd stage filter flash mixer flow control unit.

Water then flows into an in-line mixer where chlorine is dosed to control the chlorine residual to the target level. Water flows from the in-line mixer into a combined treated water channel and backwash holding tank. A new contact tank and clean water tank have been built to increase the plant flow up to a maximum of 19 tcmd and increase site storage.

Service reservoirs

Sladen Valley WTW supplies water to Lane End CRE (pumped) and feeds Bracken Bank CRE by gravity. Both CREs supply water to parts of Keighley. Additionally, there is one property that is fed directly off this main.

Table 35: A table showing the water supply zone (WSZs) fed from Sladen Valley WTW.

WTW	Water Supply Zone	% WTW Supply	WSZ Ml/d	WSZ Population
Sladen Valley	Keighley 2004	100.00%	7.95	73481

Stage Two – Hazard identification and Risk Characterisation

Provide details of methodology used to identify hazards i.e. historic data, events/ incidents including near miss situations, operator knowledge, modelling and site visits/ technical audits:

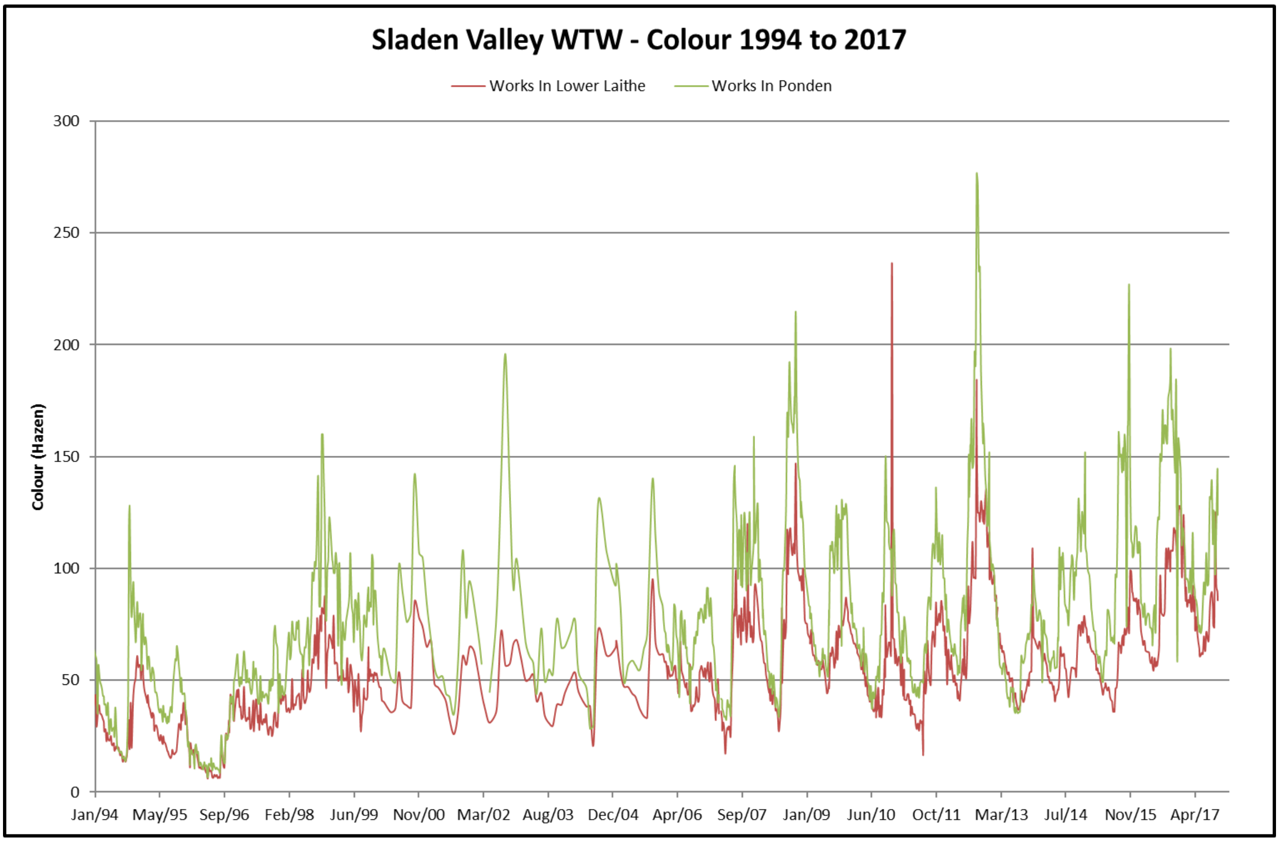


Figure. 26: Chart displaying historic to present raw water colour trend.

Table 36: WSZ THM's for Oldfield and Sladen Valley WTW 2010 to 2017.

WSZ	Year	No of Samples	Average
	2010	8	48.78
	2011	8	47.34
	2012	8	50.03
	2013	8	41.87
	2014	8	44.80
	2015	8	47.74
KEIGHLEY 2004 WSZ	2016	8	51.42

Evidence of likely to contravene any regulatory requirements

The risks as identified in the Regulation 28 report for Sladen Valley WTW are presented in table 37.

Table 37: Drinking Water Safety Planning (DWSP) risk assessment for Sladen Valley WTW.

Intolerable Risk
<u>Current Intolerable Risks</u> There are no current intolerable risks identified in Sladen Valley WTW.
<u>Future Intolerable Risks</u> There are no future intolerable risks identified in Sladen Valley WTW.
<u>Future Red Risk</u> **Risk ID –** 20044 (updated 13/10/2017) – Post risk score – 23. **Sladen Valley WTW** - Failure to sufficiently treat raw water for colour and to prevent DBP formation. **Description** - There is an increasing trend for colour at Sladen Valley WTW - Over the longer term it is likely that DBP optimisation by reducing flow and support from other WTW is unlikely to be sustainable. Future intolerable risk identified. **Predicted Year** – AMP 8 **Effect Area** – Water Quality **Risk** – Probability = Medium, Severity = Very High **Data available** – Historical water quality sample data, analysis of future trends.
<u>Current Amber Risk</u> **Risk ID –** 17487 (updated 13/10/2017) – Post risk score – 20. **Sladen Valley WTW** - Failure to sufficiently treat raw water for colour and to prevent DBP formation. **Description** - Both sources to Sladen Valley WTW are of high colour and have exceeded the internal standard. **Effect Area** – Water Quality **Risk** – Probability = Low, Severity = Very High **Data available** – Water quality sample data. **Risk ID –** 15816 (updated 13/10/2017) – Post risk score – 19. **Sladen Valley WTW** – Failure of DWW. **Description** - Issues with poor quality of the supernatant return. **Effect Area** – Filtration Services **Risk** – Probability = Medium, Severity = High **Risk ID –** 15967 (updated 13/10/2017) – Post risk score – 16. **Sladen Valley WTW** – Failure of DAP processes. **Description** - Asset is in fair condition and undergoes adequate maintenance, an upgrade would be beneficial. **Effect Area** – Clarification. **Risk** – Probability = Low, Severity = High

Details of any other data relevant to hazard identified

Table 38: A table identifying statistically significant trends in raw water colour.

	1987 - 2015 Leeds	1998 to 2015 Leeds	1998 to 2015 Leeds		
	By Month	By Month	By Year		
Site	Median	Median	Max	Mean	Min
Sladen Valley - Combined		0.77	2.83	0.98	0.08
Sladen Valley - L-laith		0.51	1.92	0.67	0.08
Sladen Valley - Ponden		0.1	2.75	0.84	0.07

KEY:	Highly sig (@1% level)	Sig (@ 5% level)	Non sig

Combined Raw and Lower Laithe both show significant upward trends in yearly means. Yearly maximum trends were not significant at 5%. Combined Raw had a P value of 9.6 % and Lower Laithe 8%. It would have been appropriate to consider trend analysis across a longer time frame, as the plant at Sladen would have been designed prior to 1993, when colour levels would have significantly lower.

Details of any events that have occurred in the catchment, WTW. None

Existing control measures – catchment

Ponden catchment is currently in a 10-year management plan with Natural England which includes various repair activities such as gully blocking, vegetation management and stabilising and raising the hydrology.

Details of monitoring control measure

The Company's operational monitoring programme includes weekly samples for colour, etc. taken at the individual WTW inlets.

Reasons for the presence of the hazard

Leeds University have completed a report investigating the occurrence and future trends in raw water colour. The investigations concluded the following reasons for the presence of raw water colour.
Over the period 1987-2015, water colour increased significantly ($p<0.01$), by between 1.5 and 4.9 Hazen/year, at 10 of the 11 sites. In contrast, over the period 1998-2015, water colour only increased significantly ($p<0.05$), by between 0.5 and 1.4 Hazen/year, at 6 of the 14 sites. This shows that the greatest rise in water colour occurred between 1987 and 1998.

Water colour was suppressed at all sites during the drought of 1995 and for several years following the drought (1996 & 1997) before increasing to very high-water colour values in 1998. Although droughts will continue to have an impact on water colour in the future, it is unlikely to be as pronounced as that observed following the 1995 drought, which was a 1 in 200 year event and coincided with a period of rapid decline in sulphur deposition. Using linear regression modelling where multiple drivers were considered together, the most successful models in predicting colour Z-score over the period 1987-2015 were those that included SO_2 emissions and summer rainfall; explaining 88-97% ($p<0.001$) of the long-term trend in colour. Summer rainfall and SO_2 emissions were also successful, but to a lesser extent, in explaining colour variation over the period 1998-2015 at most sites (r^2= 71-96%, $p<0.001$ at 5 sites).

Both models (statistical and processes) show that the biggest increase in DOC/water colour was observed in the 1990s, as a result of declining SO_4 deposition which led to an increase in soil pH and therefore an increase in DOC solubility. Both models suggest that DOC/water colour (annual and monthly mean concentrations) will be similar in 2030 as they have been in the period 2010-2015, and that in the future climate change, in particular wet summers, will have a bigger impact in controlling DOC/water colour.

Outline Risk characterisation:

Stage 3 – Control Measures Required

Details of short term actions currently in place.

Catchment Inspection and turnout

Details of mid to long terms control measures

Ponden and Lower Laithe catchments have been included in the Water Industry National Environment Programme (WINEP) to fund further repair activities. The action plan is to complete repair work on Ponden and Lower Laithe will bare peat re-vegetation, grip and gully blocking and stock removal. There opportunities to complete this work over a 15-year period.

Table 39: Sladen Valley scheme costs.

Site	Capex (£million)	Opex per annum (£million)
Sladen Valley WTW	£ 14.6	£ 0.2

Full details of how the company intends to assess and measure the benefits delivered.

The Company will use 3 main techniques to demonstrate the benefits to water quality of the proposed solutions:

1. Continuation of the long-term monitoring of raw water quality for relevant parameters – to track the progress of catchment management and corroborate on line raw water monitoring. We are about to start work on an R&D

project to identify potential solutions for real-time monitoring in locations where there is no power and communication infrastructure.

2. Use of on-line UV254 analysers (or similar) to track the DOC of incoming raw water, post MIEX, and blended raw waters – this will provide direct evidence of the amount of DOC being removed prior to coagulant dosing.

3. Structured network sampling for DBPs – currently planned to be THMs and HAAs – to include WTW outlet, SRE outlets, and customer tap samples to encompass the range of travel times within the system supplied by Oldfield WTW

Tophill Low WTW

Scheme details

Water Company:

Yorkshire Water Services Limited

Date of submission:

31st December 2017

Name of water Treatment Works/ Distribution System/ Service Reservoir/ Other asset:

Tophill Low WTW (T2698270).

Water quality hazard/ drivers identified:

Algae/ Customer acceptability/ Crypto – new filters / interstage O3 / GAC

Reference to outcome in company's long-term strategy:

Enhanced Drinking Water Quality

Stage One – Details of water treatment works and associated supply system

Provide supply arrangements and treatment works details:

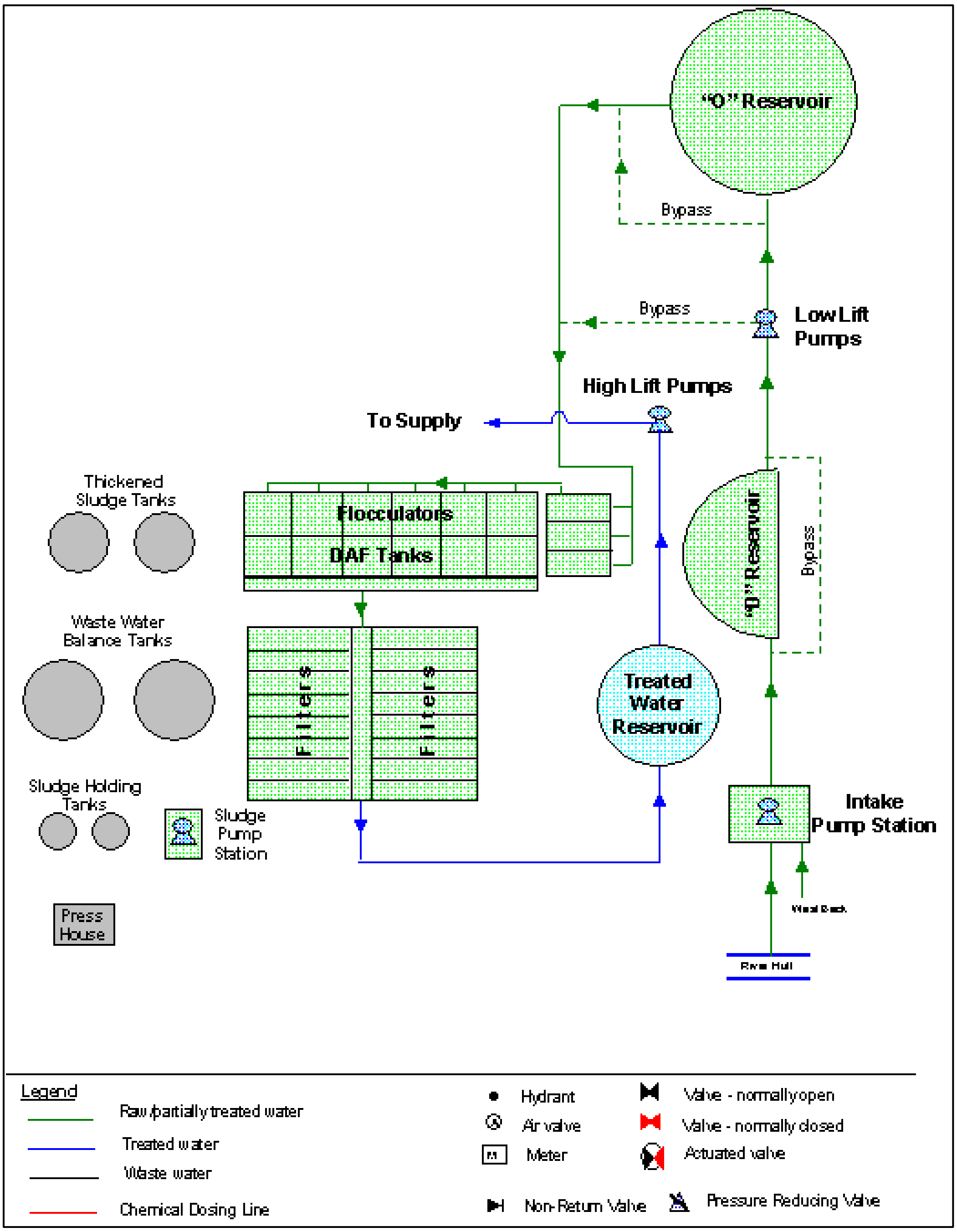


Figure. 27: Site schematic for Tophill Low WTW.

Table 40: Two tables illustrating the design and current flow capacities of Tophill Low WTW.

Design Flows (Ml/d)	Minimum	Maximum
Inlet Flow	-	-
Outlet Flow	-	68

Current Flows (Ml/d)	Minimum	Average	Maximum
Inlet Flow	10	38.68	63.99
Outlet Flow	7.2	35.56	61.28

Sources of raw water

Tophill Low WTW receives water abstracted from the River Hull at Hempholme via two storage reservoirs.

Table 41: Tophill Low WTW - Raw water source

Source Name	Source of Water
River Hull	Surface direct abstraction

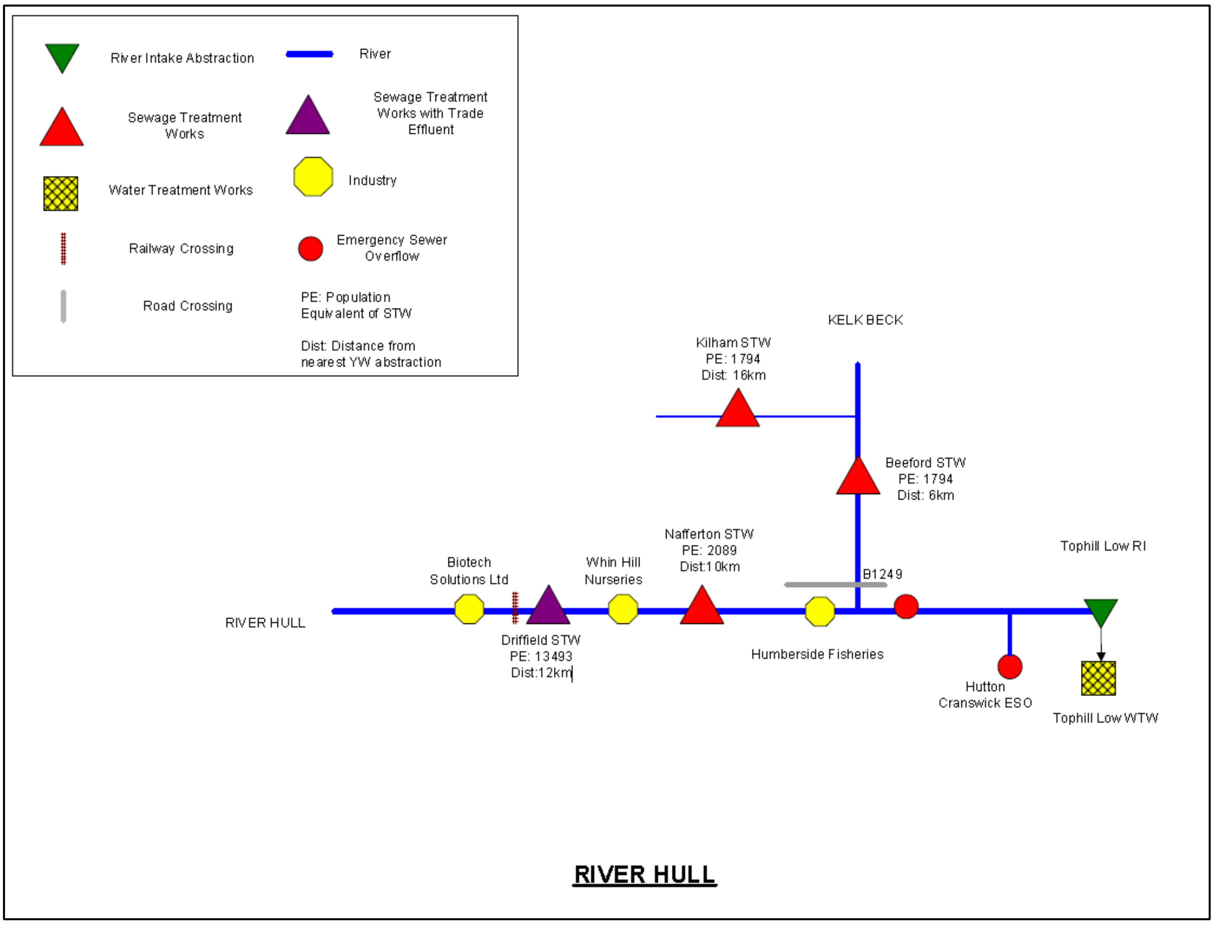


Figure. 28: Flow diagram illustrating water quality risks to River Hull abstraction point.

Treatment process

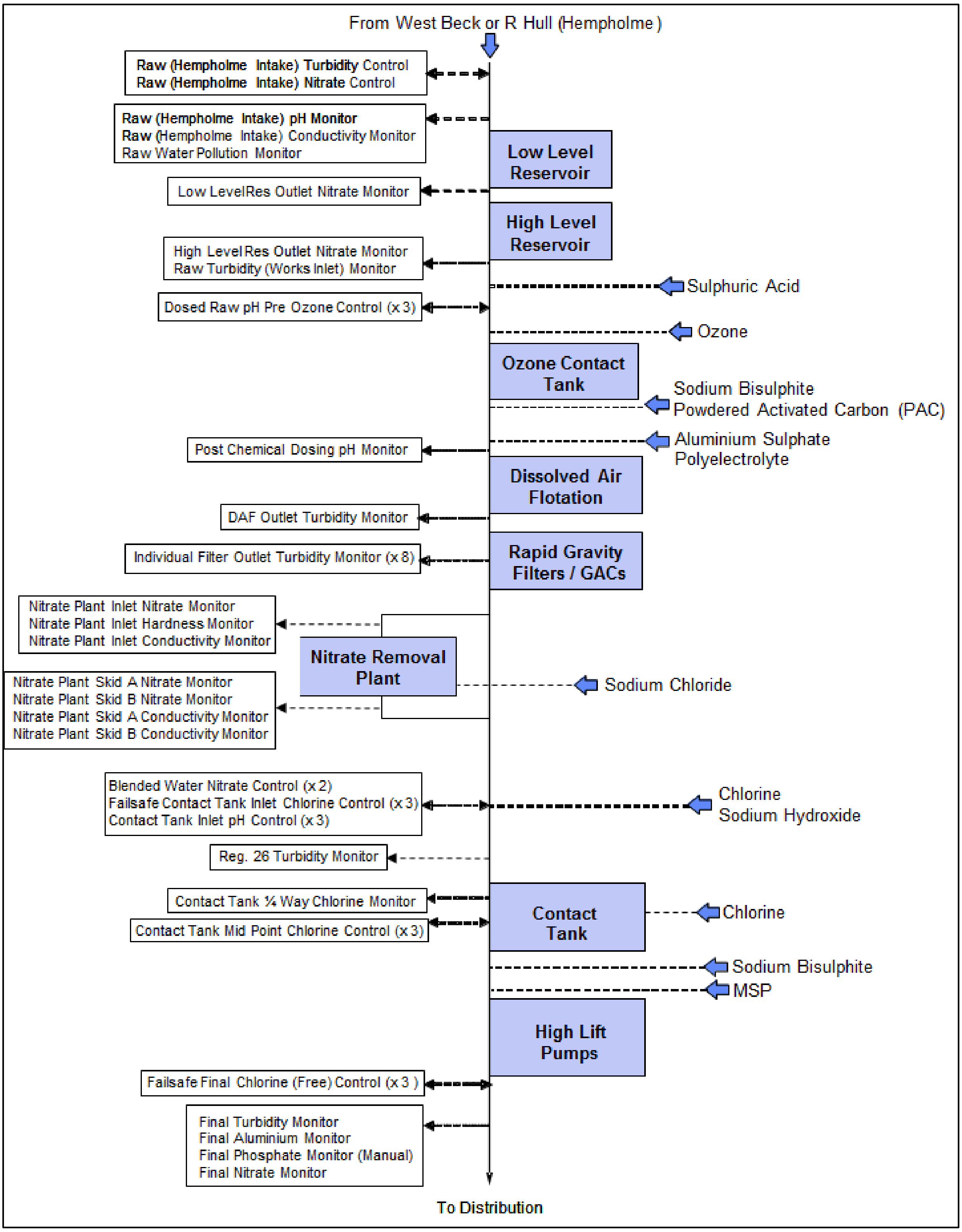


Figure. 29: Process schematic of Tophill Low WTW.

Water from the river sources flows into an intake screening chamber at Hempholme Pumping Station. From here it is pumped to the "D" reservoir for settlement (this reservoir has approximately 13 days storage capacity) and pumped from there to the "O" reservoir and then by gravity to the Ozone Contact Tanks. Water enters a static mixer which has the facility for dosing sulphuric acid (determined by the pH of the raw water). The flow is then split between the three Ozone Contact Tanks working on a 2 duty, 1 standby basis. Sodium bisulphite is dosed on the outlet for de-ozonation and the flow then passes to two flash mixers where facilities are provided for dosing with aluminium sulphate and a polyelectrolyte. Prior to the flash mixers, there is also the facility to dose powdered activated carbon for taste and odour problems.

Next in line are six flocculator units and associated flotation cells. Air saturated water is injected at the flotation cell inlet from a DAF saturation system. Surface sludge is removed to the Dirty Washwater Pumping Station. Clarified water leaves the DAF units and enters a common filter inlet channel where the flow is split between eight dual media (sand/GAC) rapid gravity filters.

The outlet from the filters can then either flow directly to the chemical dosing & blending static mixer or the flow can be split prior to the mixer with a side stream passing to the Nitrate Removal Plant.

At the Static Mixer, Chlorine and Sodium Hydroxide (for pH correction) are dosed prior to the flow entering the Clean Water Tank where final disinfection takes place. Sodium Bisulphite is dosed on the CWT outlet prior to the High Lift Sump to maintain a specified chlorine residual. Sodium Dihydrogen Orthophosphate (MSP) is dosed at the High Lift Sump to aid plumbosolvency in the distribution mains.

Service reservoirs

Tophill Low WTW supplies part of the East side of Hull and from Tickton down to Holderness. It is therefore a strategic site, supplying the Distribution system both directly and through a series of Service Reservoirs.

Table 42: A table showing the water supply zone (WSZs) fed from Tophill Low WTW.

WTW	Water Supply Zone	% WTW Supply	WSZ Ml/d	WSZ Population
Tophill Low	Beverley 2004	2.64%	0.99	97182
Tophill Low	Holderness 2008	64.29%	24.24	98434
Tophill Low	Hornsea 2008	33.08%	12.47	97729

Stage Two – Hazard identification and Risk Characterisation

Provide details of methodology used to identify hazards i.e. historic data, events/ incidents including near miss situations, operator knowledge, modelling and site visits/ technical audits:

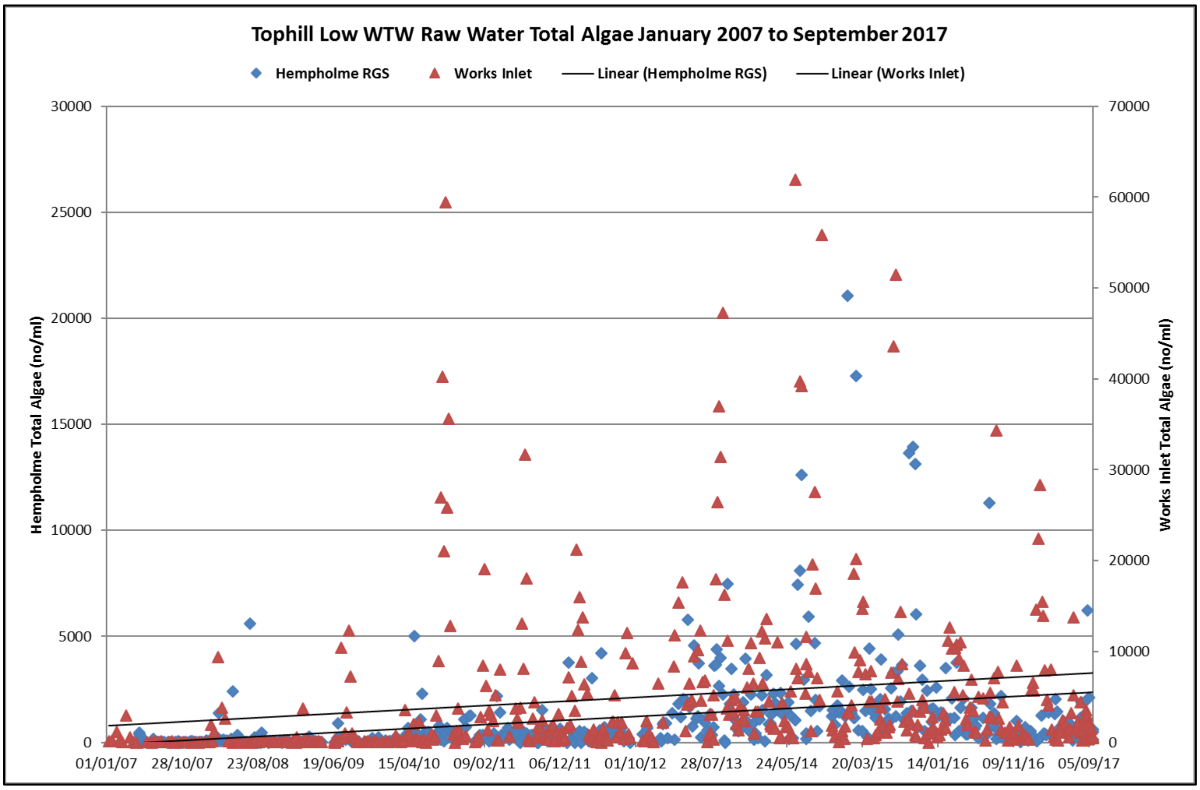


Figure. 30: Chart displaying total algal data trends at Tophill Low WTW.

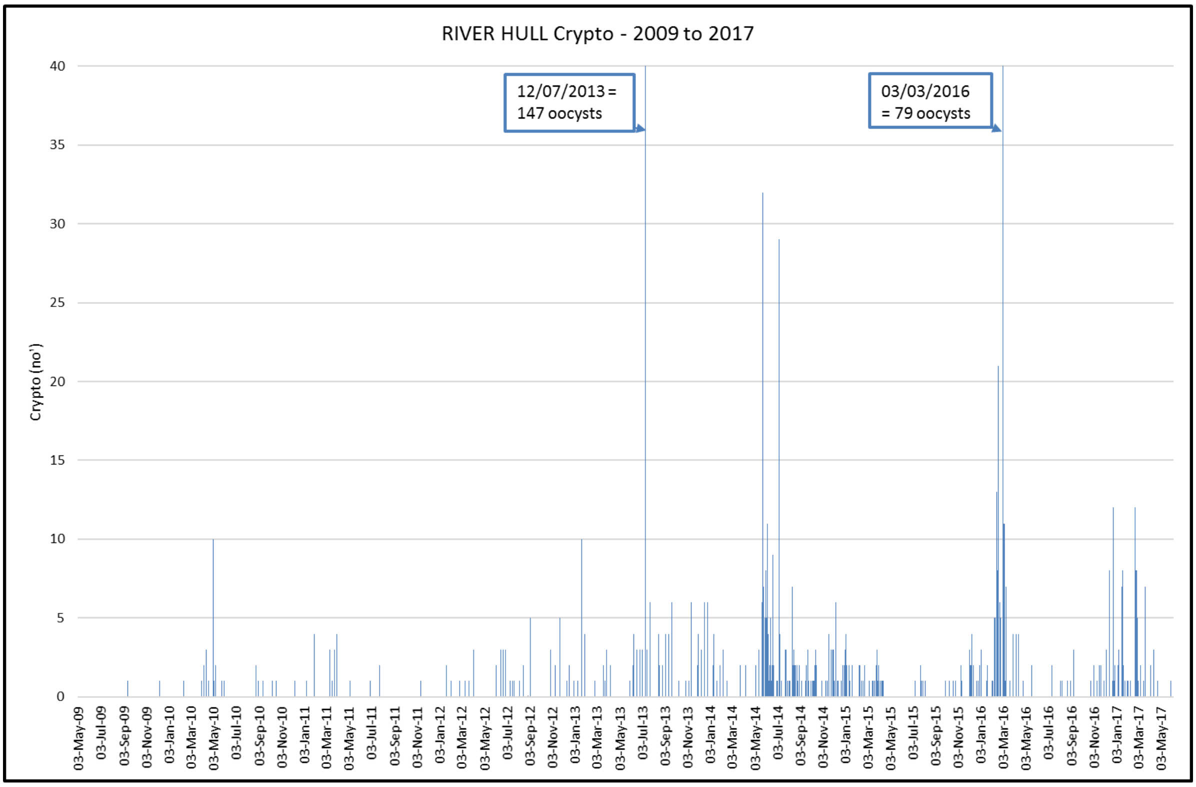


Figure. 31: Chart displaying crypto detected at River Hull abstraction point from 2009 to 2017.

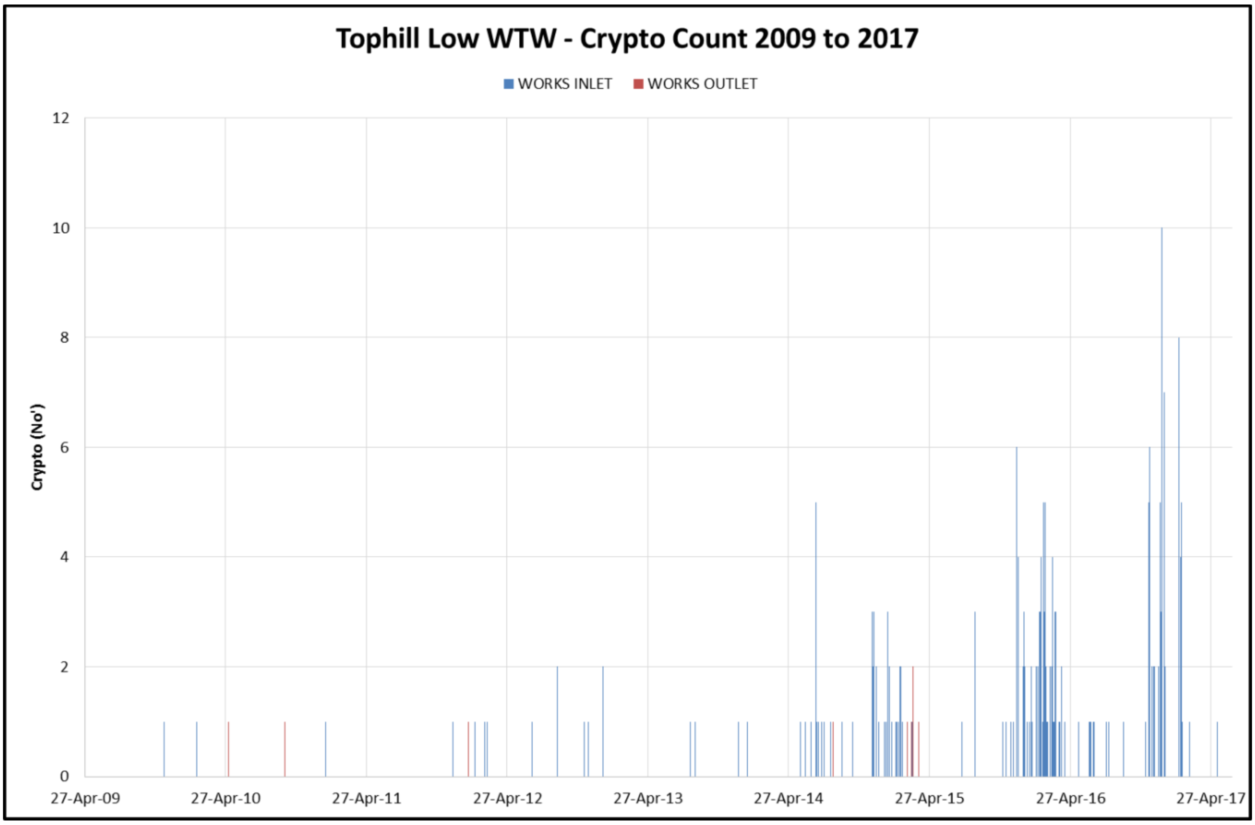


Figure. 32: Chart displaying crypto detected at Tophill Low WTW inlet and outlet from 2009 to 2017.

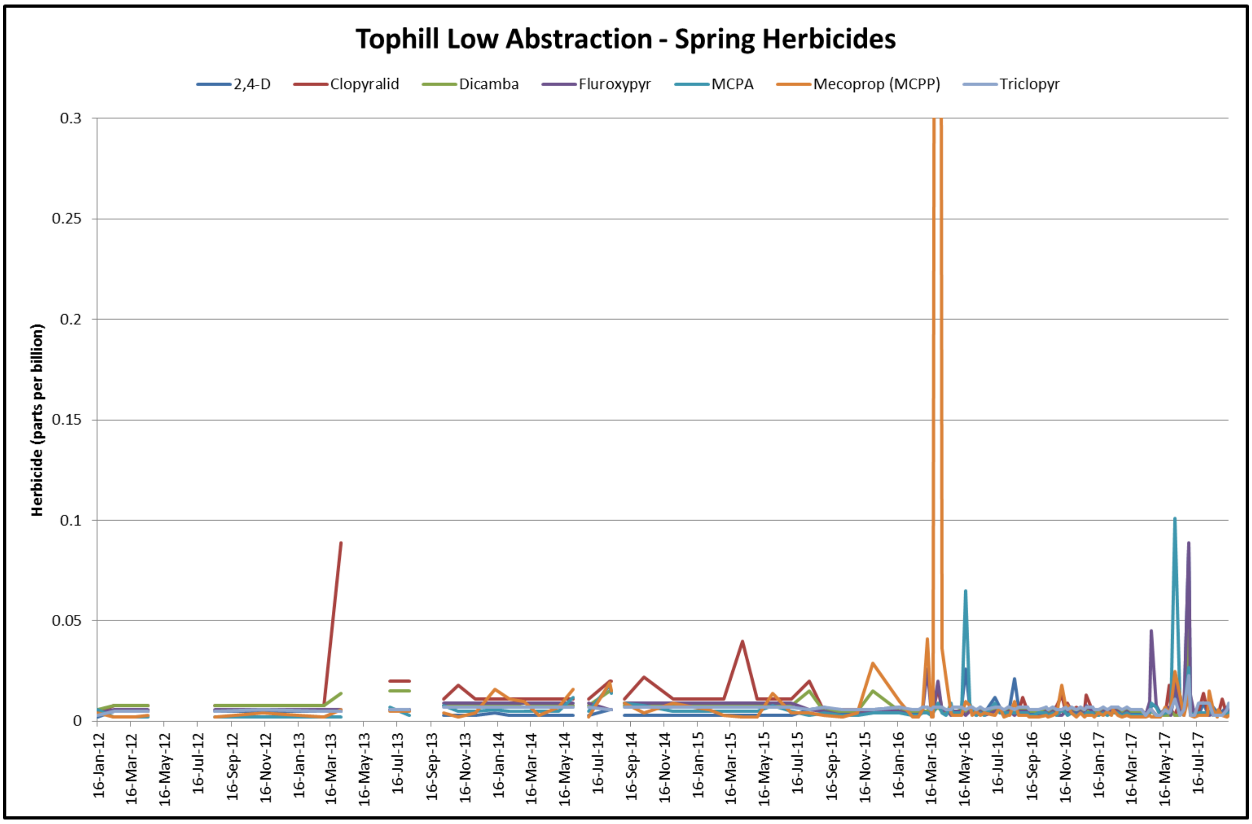


Figure. 33: Chart displaying Spring herbicide detections at Tophill Low WTW abstraction from 2012 to 2017.

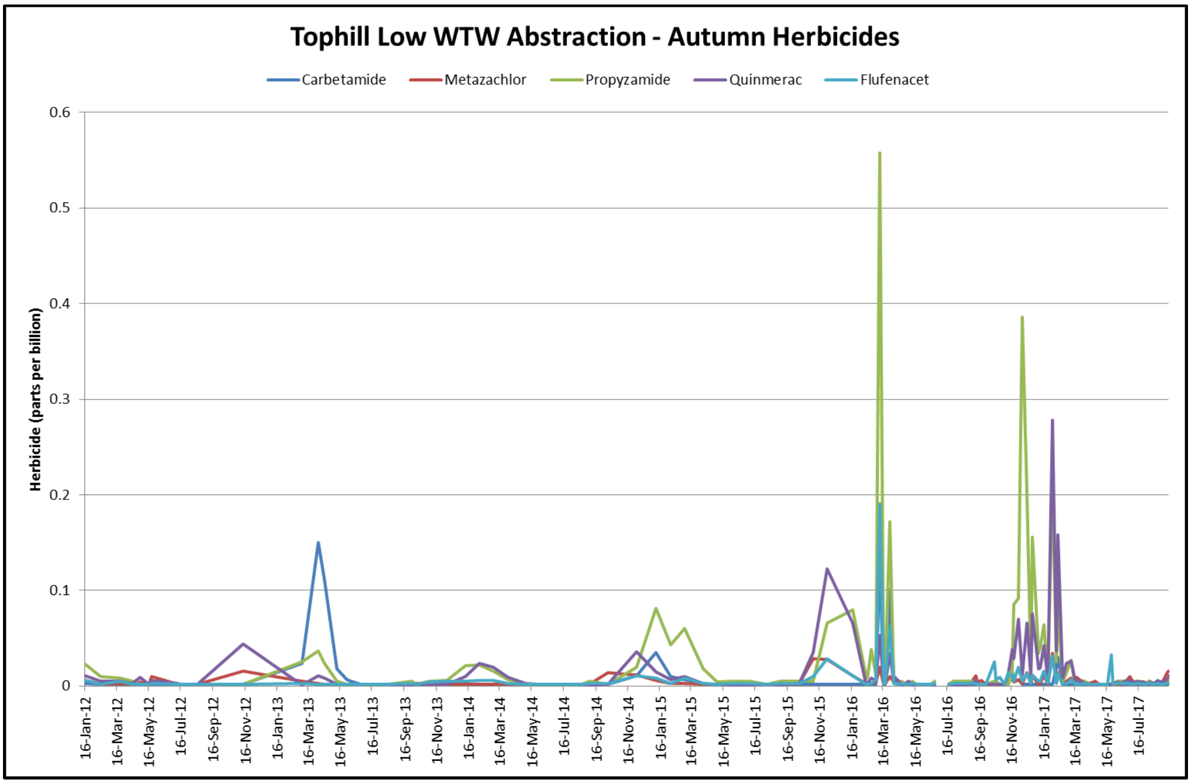


Figure. 34: Chart displaying Autumn herbicide detections at Tophill Low WTW abstraction from 2012 to 2017.

Details of any existing contraventions of regulatory requirements

The risks as identified in the Regulation 28 report for Tophill Low WTW are presented in table 43.

Table 43: Drinking Water Safety Planning (DWSP) risk assessment for Tophill Low WTW.

Intolerable Risk
Current Intolerable Risks **Tophill Low WTW** – Failure of treatment process to control Metaldehyde levels entering supply – Risk ID – 16331 – Post risk score – 24. **Description** – The River Hull has been identified as high risk because of land use practices used within the catchment. Previous levels have been above PCV during Metaldehyde usage season. **Effected Area** – Water Quality **Risk** - Probability = High, Severity = Very High **Data Available** - Historical water quality sample data and land cover maps.
Future Intolerable Risks There are no future intolerable risks at Tophill Low WTW.
Red Risks
Current Red Risks **Tophill Low WTW** – Failure of PAC dosing – Risk ID – 16266 – Post risk score - 23 **Description** – Common occurrence T&O causing compounds in the raw water. Potential for customer complaints without appropriate PAC dosing. DWI reportable incident in Apr16 - T&O issues occurred, concerns raised over the PAC dosing system.

Effected Area – Water Quality
Risk - Probability = Medium, Severity = Very High
Data Available - Historical water quality sample data and consumer complaints data.

Tophill Low WTW – Failure of treatment process to remove taste and odour causing compounds from raw water. – Risk ID – 16337 – Post risk score **-** 23
Description – There is a significant Algae Risk to the water entering Tophill Low WTW as the onsite raw water storage reservoirs containing River Hull water are potentially high in algae. Known history of T&O problems in distribution.
Effected Area – Water Quality
Risk - Probability = Medium, Severity = Very High
Data Available - Historical water quality sample data and consumer complaints data.

Future Red risks
There are no future red risks at Tophill Low WTW.

Amber Risks

Tophill Low WTW – Failure of WTW to adequately remove *Cryptosporidium* – Risk ID – 14543 – Post risk score – 20.
Description – Current trend in oocysts at raw water inlet suggest that improved WTW mitigation will be required in the near future. CM opportunities appear limited as cause is likely to be bird populations on RW reservoirs – which are SSSI designated. No similar trend in river water as abstracted.
Effected Area – Water Quality
Risk - Probability = Low, Severity = Very High
Data Available - Historical water quality sample data

Tophill Low WTW – Failure of asset due to condition or design (RGF Media) – Risk ID – 16244 – Post risk score – 16.
Description – Current "hybrid" filter media is less effective as a particle removal stage**.**
Effected Area – Water Quality
Risk - Probability = Low, Severity = High

Tophill Low WTW – Failure of works to control pesticide levels entering supply – Risk ID – 16330 – Post risk score – 13.
Description – Due to low EBCT ~5m and lack of ozone pesticide removal is constrained.
Effected Area – Water Quality
Risk - Probability = Very Low, Severity = Very High
Data Available - Historical water quality sample data.

Summary of consumer complaints

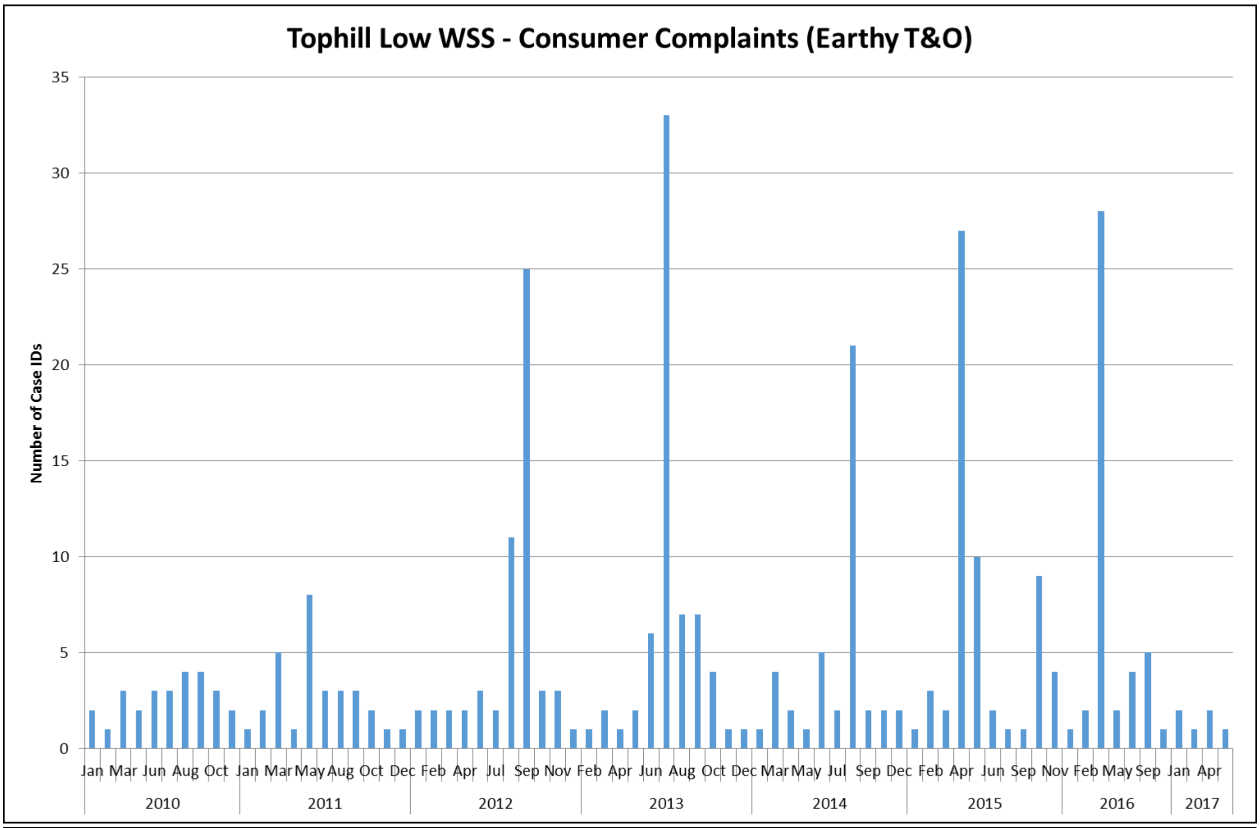


Figure. 35: Chart illustrating annual trend in T&O consumer complaints within Tophill Low WSS.

Table 44: Table to display the monthly changes in T&O complaints from 2010 to 2017.

Earthy T&O Consumer Complaints - Count of Case IDs

Month	2010	2011	2012	2013	2014	2015	2016	2017	Grand Total
Jan	2	1	2			1	1	2	9
Feb	1	2	2	1	1	3	2	1	13
Mar	3	5	2	2	4	2			18
Apr		1	2	1	2	27	28	2	63
May	2	8	3	2	1	10	2	1	29
Jun	3	3		6	5	2	4		23
Jul	3		2	33	2				40
Aug	4	3	11	7	21	1			47
Sep	4	3	25	7	2	1	5		47
Oct	3	2	3	4	2	9	1		24
Nov	2	1	3	1		4			11
Dec		1	1	1	2				5
Grand Total	**27**	**30**	**56**	**65**	**42**	**60**	**43**	**6**	**329**

Details of any events that have occurred in the catchment, or at the WTW

There are no recorded Event associated with the catchment; the following events are recorded at the WTW site.

TOP 09	2009 - 2386	Tophill Low WTW - E. coli detection	15/07/2009
TOP 14	2014 - 4472	Tophill Low WTW - *Cryptosporidium* Detection	01/06/2014
TOP - 16	2016 - 5509	Tophill Low WTW - Taste and Odour issues	22/04/2016
THL - 17	2017 - 6211	Tophill Low WTW - Elevated Turbidity -	22.08.2017

Details of any existing control measures that might influence the values

Cryptosporidium – Two onsite raw water storage reservoirs. The reservoirs enable settlement of oocysts and inactivation of oocysts by UV, water temperature and by filter feeders and grazers.
Commissioning of new PAC dosing plant which allows the consistent dosing of higher concentrations into the raw water. However, the increased dose has a significant impact on the capability of the site to produce water, reducing flow to around 50% when PAC doses are high in the summer months.

Details of monitoring control measure

The Company's operational monitoring programme includes weekly samples for crypto, T&O, algae, etc. taken at the individual WTW inlets.

Details of any changes in practices or policy

None

Details of any licence abstraction issues

None – currently in discussions with EA/N England regarding opportunities around the abstraction to reduce the risk from metaldehyde – no significant impact on Crypto loading anticipated.

Reasons for the presence of the hazard

Algae – Algal growth driven by nutrients in the River Hull. The main sources of nutrients are from agriculture (artificial fertilisers and spreading of slurry/manure) and effluent from Driffield WWTW and CSOs. Additionally, nutrients input from roosting birds on the storage reservoirs. Furthermore, large sections of key tributaries to the River Hull are shallow and not shaded, therefore this increases the risk of increased water temperature and thus algae growth.

Cryptosporidium – sources of crypto oocysts at a reservoir inlet can be from animals or humans. Animal sources can occur due to activities in the catchment such as animal grazing, manure and slurry spreading and storage. Human sources can occur due to wastewater treatment works discharges, storm-water overflows and septic tanks being present in the catchment.

Outline Risk characterisation:

Stage 3 – Control Measures Required

Provide details of short, medium and long-term control measures i.e.

Details of short term actions currently in place

- Abstraction management.
- PAC dosing

Details of mid to long term control measures

Catchment- The River Hull catchment is within a Natural England Countryside Stewardship high priority area for water quality including phosphates, nitrates and pesticides. Within those priority areas incentives are offered to farmers to adopt agricultural practices which will safeguard areas and meet the Water Framework Directive. The incentives can help enable farmers to improve farm infrastructure and deploy in field mitigations against nutrients and crypto losses to the watercourse.

WWTW - The current technical limit for phosphorus removal at the WWTW is 0.5 mg/l annual average. There is currently a national trial to understand whether the limit could be further reduced to 0.1 mg/l annual average from 2020. The success of this trial can then start to initiate changes to be made to all WWTWs and thus therefore reduce the nutrient loading from the WWTWs.

Options the company has considered e.g. catchment management

The River Hull catchment has been included in the Water Industry National Environment Programme (WINEP) to fund catchment officers. The action plan is to increase the level of engagement on water quality and allied matters within the catchment and to utilise learning from our activities in other catchments.

Table 45: WINEP submission for the River Hull catchment for nitrate.

Driver Description	WINEPID	Function	RBD	Area	Water Company	Unique ID	Scheme Name	Waterbody	Waterbody ID	Water Body Type(s)	WFD Catchment	Driver Code
Investigation / Options appraisal for Flow regime	YOR00010	WR	Humber	Yorkshire	Yorkshire Water Service Ltd	7YW100075	BOREHOLES - CHALK - KILHAM	Gypsey Race from Source to North Sea	GB1040260 72790	River	Gypsey Race	WFD_INV_W RFlow
Drinking Water Protected Areas	YOR00196	WQ	Humber	Yorkshire	Yorkshire Water Service Ltd	7YW200140	CSF officers Yorkshire wide all parameters	Catchment Scale	Catchment Scale	Catchment Scale	Catchment Scale	DrWPA_ND

Table 46: Tophill Low WTW scheme costs.

Site	Capex (£million)	Opex per annum (£million)
Tophill Low WTW	£ 16.3	£ 0.4

Full details of how the company intends to assess and measure the benefits delivered.

Cryptosporidium – continuation of current monitoring – regular river and raw water samples, with continuous sampling of treated water / application of the Company Filter Management Process which monthly reviews the performance of all individual RGFs with respect to turbidity removal to identify gradual deterioration in performance / application of RGF outlet turbidity targets to continuous monitoring data

Acceptability – routine monitoring of MIB/geosmin in treated water / daily surveillance of treated water T&O by site personnel or sampling officers.