A7: Innovation to deliver better outcomes

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OVERVIEW: ABOUT THIS DOCUMENT

This appendix is part of our 2020-2025 business plan submission. It builds on the markets and innovation chapter in our main business plan.

This appendix comprises **two** parts:

Part 1 – how we've made a step change to embed innovation in our business; and

Part 2 – case studies representing a wide variety of our innovative work so far.

Contents

PART 1: DRIVING INNOVATION IN THE SECTOR TO DELIVER BETTER OUTCOMES

Driving innovation in the sector to deliver better outcomes

Innovation is an integral part of what we do. It's locked into our strategic framework as an objective to 'drive operational excellence and continuous innovation' and underpins how we will achieve our company purpose to serve our communities. We know that during AMP7, innovation must be at the forefront of everything we do, as we seek to deliver a stretching suite of performance commitments, while keeping bills lower.

We believe innovation can be anything from the small ideas for change that improve our everyday service - but can add up to being game-changing, to the big disruptive ideas that truly revolutionise what we do – making some activities redundant, and introducing entirely new ones.

Innovation is already evident in every area of our business, examples of which include:

- **Our technology** – we invested in new treatment technologies to improve the quality of our biosolids – creating a better product for the new market, a better source of renewable energy and reduce our carbon footprint.
- **Our processes** – we used the proceeds from outperformance to introduce a new, specially trained care and assistance team that provides bespoke support to our customers with specific needs.
- **Our people** – we de-layered management in our organisation and empowered all our people to strive to make things better for our customers every day.
- **Our relationships** – we retendered our major supply contracts so there's a clear line of sight from customers' priorities to our incentives (ODIs) and our supply chain's performance.
- **Our business models** – we restructured part of our company into a joint venture to create a competitive offering for customers in the new retail market

In this section, we explain:

- the innovation infrastructure we introduced for AMP6;
- the source of the ideas that drive change;
- the tools we use to capture and nurture those ideas; and
- how our innovation strategy is looking to AMP7, 2045 and beyond.

Read more: Part 2 of this Appendix include case studies showcasing some of the innovations that are making a difference to our business and Chapters 10-18 include shorter case studies in the context of the outcomes that they're helping to deliver.

An ambitious step change in innovation for AMP6

We have a long track record of innovation within the water industry. Like most water companies, since privatisation in 1989 we've had a dedicated research and development team. But in AMP6 we decided to make a step change to take the opportunities of an outcomes based regulatory framework.

Doubling our investment in innovation

As a sign of our commitment to be the sector's leader in innovation, we've more than doubled our totex investment from circa £20 million in AMP5 to £42 million in AMP6 and we believe our proposed investment spend this AMP will be one of the largest in the sector (based on available information in companies' annual report and accounts).

Embracing greater freedom to innovate

Our 2010 *Changing Course* report, which preceded the 2011 Cave Review, articulated the need for greater innovation in the sector. We suggested that changes in economic regulation – including a greater focus on outcomes and more flexibility for companies to deliver them – would help.

Since the introduction of Ofwat's outcomes based incentives framework at the 2014 price review, we've embraced the opportunities provided by this new approach and thought differently about how to deliver performance.

We took risks with innovation early in this AMP in order to deliver rapid improvements. For example, three months into 2014/15 we had a run rate of sewer flooding incidents that would equate to a £45m penalty. We reversed this trend by taking a new approach to how we used our data and by engaging with our customers in blockage 'hotspots'- some 84,000 in our first year. This more proactive approach resulted in a 31% reduction in internal and 28% reduction in external sewer flooding for our customers.

It means we've been able to create a virtuous cycle of innovation. Outperformance (generated from across our company) gives us more freedom to take risks with innovation, which, if it delivers better outcomes, in turn generates more outperformance. So our customers benefit from better service, an improved environment and a more sustainable company – while their bills remain the lowest in the country.

Global benchmarking

In 2015 we looked outside our sector to build what we believe is a best-in-class innovation model. We commissioned a global benchmarking exercise to capture how leading companies (including companies like Pfizer and Philips) approach innovation. We subsequently adopted a model that includes a team with specialist innovation management roles and is unique within the UK water sector. We believe, for example, that we are the only water company to have a front end innovation team that focuses solely on innovation needs and idea generation. We published our 'innovation needs' document in November 2015 which is referenced throughout this document.

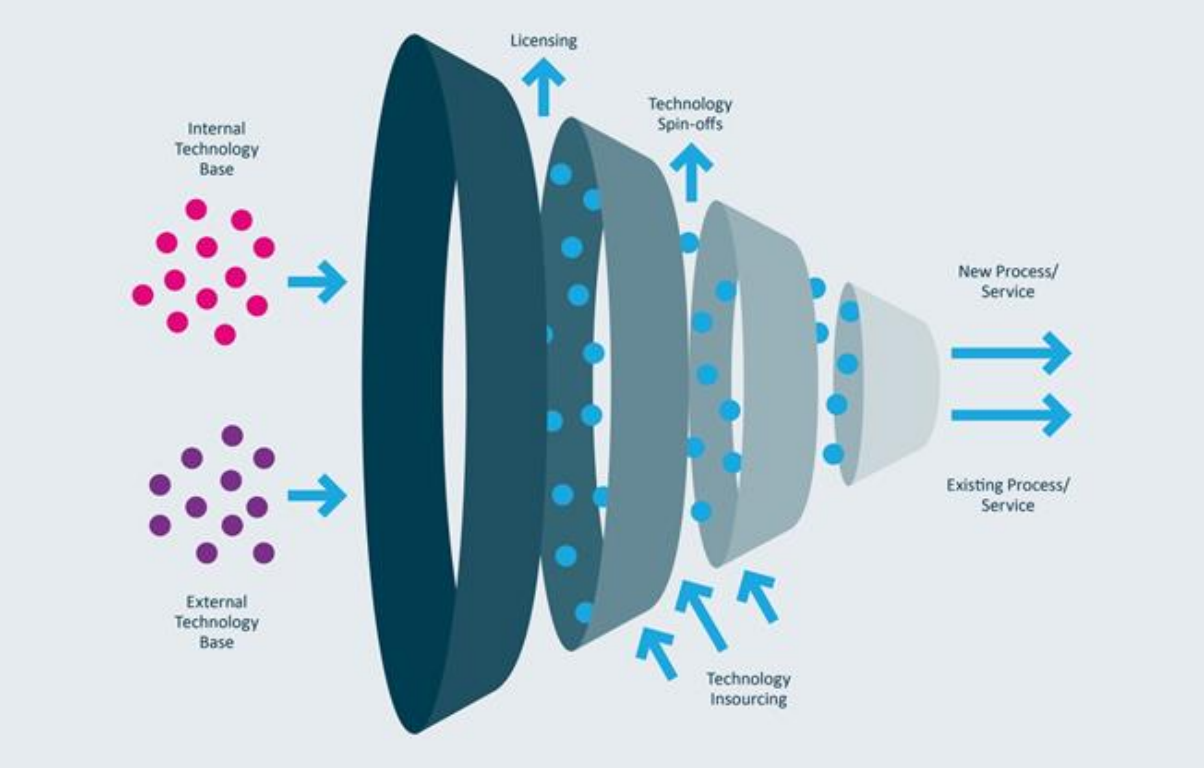
Five dedicated teams focused on all parts of the innovation value chain aligned with best practice

Our central innovation team works in parallel with other innovation hubs in our business – including our customer, digital and group commercial teams.

Open innovation to find the best ideas

Instead of a more traditional 'closed' approach to innovation, we adopted an open innovation model. This collaborative approach enables us to actively seek and bring innovation to the water industry from academia and other sectors. We believe it is a more efficient approach for our customers too.

Open innovation allows for flow of expertise and ideas between organisations



Open innovation allows the flow of expertise and intellectual property between organisations. We bring in research skills from universities or license our intellectual property to manufacturers, to enable them to deliver new goods and services into the water industry. This approach has led to many innovations including a next-generation leak detection device – the LeakFinder ST – which is protected by patent in the UK and seven other countries.

Open innovation has significantly increased the number of potential ideas and technologies we could adopt. We use a recognised Stage-Gate® process to support the evaluation, delivery and implementation of projects, underpinned by 'Bubble Innovator ™', a dedicated software package to manage our innovation portfolio. Bubble was selected as part of a multi-sector benchmarking exercise to help us implement a best-in-class approach to innovation. The software is vital to ensuring our extensive portfolio is effectively managed and the benefits can be tracked wherever innovation occurs across our organisation. The process has enabled us to increase our focus and reduce the number of active projects from 100 to 25 - ensuring we efficiently target our efforts on our key needs.

Focusing innovation on outcomes

We make an open call for innovation in our annually published 'needs document'. In it we set out our short and longer term needs and the gaps we need to meet through innovation. The document is structured around the outcomes in our business plan and the improvements we've committed to deliver. We don't constrain innovation to just these areas – we believe innovation should be encouraged anytime, from anyone, and anywhere it can bring benefit. However, having a central focus directly aligned to business plan outcomes ensures we're channelling innovation where it benefits our customers most.

It’s from this foundation that we’ll address our 2020-25 innovation challenge – delivering better service and greater resilience, while keeping bills lower.

The ideas that drive change

The ideas that fuel our innovation come from both inside and outside our company. First and foremost, we have a culture with innovation embedded at its heart.

An ‘anyone can innovate’ culture

Our ‘anyone can innovate’ culture rocketed with a new organisational structure that de-layered five tiers of management, empowered people, and allowed for more dynamic decision making. All employees were taken offline and briefed in person about the customer culture and service changes we wanted to make. Everyone was given permission to try new approaches and, importantly for innovation, make mistakes – from which we can constructively learn.

This year we've given every employee downtime to innovate. Through 64 roadshows across our region, our Chief Executive met with over 5,500 people to inspire them to tackle two of our strategic innovation ambitions:

- reduce leakage by 15% in the next 5 years; and
- reduce the amount of water we abstract by 50% in 10 years.

Known as the *Bike on a boat* roadshow, this event drew on the spirit of New Zealand’s winning America’s Cup sailing team, who installed pedal power on their yacht as an alternative to winching sails by hand. The term is now synonymous with innovation in our organisation.

And because solid performance gives us more freedom to innovate, we’ve launched our innovation scouting *Bike on a boat* international fund. Through a competitive process, all our people are encouraged to apply for the opportunity to find out more about how innovation is changing the water sector and other industries across the world - to learn from them, and bring back the very best to explore further. And the ideas they found are reflected in our plan – for example, our water academy borrows from a model used in Singapore, and the effluent reuse we learned about in Namibia is shaping our strategy for our ‘thriving environment’ outcome.

We actively create other opportunities for our employees to generate ideas around specific business challenges. These initiatives include ‘The Challenge Cup’, our internal crowd sourcing platform #BrightSparks, and our ‘OpenInnovation’ ideas inbox.

Innovation sparked by our customers

Our customers offer us a wealth of insight every day that we can use to inspire change. Our ‘voice of the customer’ tool provides us with instant feedback, while our newly established customer panel Tap Chat allows us to generate and explore new ideas with over 15,000 customers.

Using an advanced analytics tool, we can connect millions of rows of data from multiple disparate data sources to gain a more granular view of our customers. This allows us to generate models that assign a cost to serve per customer type and helps to generate initiatives that improve service and increase efficiencies.

Our customer behavioural insights team focuses on using both existing and trial data to explore influences on consumer behaviour. In two recent trials, we used a data-led approach to promoting water efficiency and payment by direct debit. Both campaigns drove an increase in performance against previous marketing activity.

Using data in this way will be a critical enabler for our 2020-25 plan. It will underpin how we'll inspire behavioural change towards our sewers and water use as well as helping us to better predict when our customers may be at risk of falling into debt (so we can proactively help them) and tailoring our communications to our customers' preferences.

Innovation from, and for, our communities

We want our innovation culture to benefit our whole region, and in turn we look to draw innovative ideas from our regional stakeholders.

We introduced an innovative 'partnership working' performance commitment to support us working with other organisations to resolve flooding that could not be addressed in isolation. We've not only successfully delivered eight partnership schemes so far this AMP, we're on track to deliver our target of 21 - and we also now have a much more complete picture of flooding in our communities. We created an online sharing platform (in the form of a GIS map) to help our partner risk management authorities find crossovers between our respective priorities. This will help us to increase the opportunities for co-creation and co-delivery with our partners in AMP7 – reflected in our new collaborative flood resilience performance commitment.

We also look for innovative ideas from our communities. During 2020-25, we're committing to our biggest ever leakage reduction of 15%, in five years. To hunt for new ideas in 2017 we hosted three events over four days at the Coventry and Warwickshire Business Festival – an Expo, a Design Sprint and a Hackathon - focusing on solving leakage. We attracted 174 participants from 53 organisations who donated 1253 expert hours. Three trials are currently under consideration together with exploratory work on five technologies from the Expo. And we're progressing seven ideas generated from the Design Sprint and Hackathon.

Incentivising innovation in our supply chain

There's huge potential to both incentivise innovation from our supply chain, and innovate in how we construct commercial contracts.

In the current period we restructured and retendered all of our significant contracts to eliminate unnecessary costs, aligning performance objectives to our strategy and simplifying our processes to be more effective in our interventions. This includes our sewerage commercial model, chemicals, IS telecoms and facilities management.

As part of our sewerage commercial model, we revised incentive arrangements to better align with our ODI framework. Our earlier arrangement led suppliers to be both risk averse and inflate rates to protect themselves from worst case scenarios. Removing this allowed base costs to be reduced in line with the supplier's risk incurred. And a replacement incentive mechanism was introduced, aligned to the new ODIs to reward good performance. The incentive is funded from the total saving in base costs following framework re-negotiation and not from additional revenue from customers as a result of ODI outperformance.

We also know that changes in external markets could mean that standing still with our commercial contracts could compromise our future efficiency. So ready for 2020-25, we're retendering our supply chain contracts. This process, which included creating seven potential future worlds to test operating models against, is designed to ensure that our partnership with our major suppliers continues to deliver the best possible value for money as we deliver our next plan.

Read more: Chapter 20: Securing cost efficiency explains more about our new 'one supply chain' procurement process.

The power of data

We're constantly evolving, using technology to become a truly insight driven organisation. Our information and data transformation programme is working towards an ultimate goal of teams using self-service (rather than a central business information team) as a matter of course to make decisions, drive efficiency and performance and support innovation. This includes collaborating externally to push the boundaries of the value we can get from our data.

The programme undertakes proof of value exercises as it progresses to ensure we're investing our customers' money well. Its first exercise focused on leakage. Working with a strategic partner in advanced analytics, we've created a model that uses 24 algorithms and 2.7 billion rows of existing operational data to identify the characteristics of our pipes – e.g. age, repair history, changes in flow and pressure – that lead to leaks. By applying these algorithms to our network to predict where issues could arise, the trial has been able to reduce leakage detection time by around 70%.

Adapting innovation from other sectors

Part of the ethos of an open innovation approach is that we should seek to learn from others. This might include, for example, developments in the competitive non-household retail market which could be relevant to household customers. But we also look further afield. Many of the issues faced by the water industry are also common to other sectors. Therefore, we actively seek relevant innovations from other sectors and work closely with technology providers to adapt their products to meet our needs. A recent example of this is how we've used a pollution control technology from the petro-chemical industry to remove blockages caused by fats, oils and grease in our sewers.

Development of innovation from idea to product can be an expensive and extended process, with many small innovators relying on grant funding. We play an active part in this process and support SMEs with grant applications. By partnering with us, they're able to gain valuable insight into the technical issues and the market for their technology, which is a key step to secure funding.

We also work with SMEs in our supply chain to help us commercialise our in-house innovation, which in many cases also adds value to their existing product range.

A global outlook

We undertake global benchmarking and visit other parts of the world to understand how organisations are dealing with significant global challenges, such as climate change and water scarcity. A recent visit to Singapore, for example, has strongly influenced our thinking on metering, leakage and how we could increase the technical skills of our workforce with a centre of excellence for learning. It has also helped us build global collaborative networks in Asia, Australia and the US.

We exchange information with utilities from outside the UK who are recognised as leaders in adopting innovation – including utilities in the US and the Netherlands - and research organisations such as the Dutch Water R&D network and the North America based Water Research Foundation. And currently, we are the only UK water company to subscribe to BlueTech Research, which provides an evaluation and benchmarking service for technologies from around the world.

The tools we use

We're always expanding the toolkit we use to find and develop innovative ideas.

Adopting a start-up mentality for digital technology

We believe our approach to technology innovation is truly unique in the water sector. Our digital technology innovation team uses a lean startup approach with small company agility. Using the principles behind Eric Ries' publication 'The Lean Startup', the team focuses on being less wasteful to find great ideas (and filter out the not so great).

Supported by Atkins and Fluxx, we use their digital incubator toolkit to rapidly develop and validate our new business ideas. The process is exceptionally quick, allowing ideas to be taken from experiment to learnings, then validation of learnings – all in the space of a week. At the end of the week a video and email are shared with selected employees, including the executive committee and our Chief Executive, to fast track ideas that show promise.

Creating an Uber for leaks?

Working with the Atkins Digital Incubator, the Leak Locator project sought to test the customer desirability, business viability and technical feasibility of a new 'Uber for Leaks' service to address our leakage challenge. By setting up a pay-per-leak gig economy platform, we aimed to get the information required to build a job more quickly than the current average of 48 hours.

The project was our first to use a lean startup "Build, Measure, Learn" approach. Each week we ran a new experiment to iteratively deliver value and insight about how a scaled-up service could work. In the spirit of Lean, we didn't invest in any technology up front and instead used free online tools such as Facebook Messenger and PayPal to test desirability and feasibility.

We found that students were particularly interested in signing up for the service – we signed up 42 in a single week-long sprint. We ran several live iterations through Facebook Messenger and established that the most effective way to reduce time taken to get to a leak is to stagger payments, depending on time taken to reach the leak location.

The final live test involved building a critical mass of users in a small area to understand how a future service would work at scale. Using staggered payments and the ability to rapidly notify multiple users to a new leak, we reduced time taken to attend a leak to an average of 1 hour 9 minutes.

One of our most challenging performance commitments this AMP and continuing into the next, is reducing the time it takes to respond to leaks. On a similar vein to the case study above, our digital innovation team have begun trialling video calls, willing customers to identify leaks. We receive around 40,000 calls relating to leakage each year – but it is often difficult to identify the issue over the phone, meaning a visit from a technician is often needed. Video calls between our customers and technicians could raise jobs more swiftly because we're able to identify the issue faster. Initial results look promising - 80% of customers were willing to take a video call – resulting in around three-quarters of these not requiring a visit. We've also received great feedback from customers – with 75% giving us a 5* score for interaction.

Finding the best ideas from our people

As we undertook our customer engagement programme for this plan, we consistently heard from our customers that we can make their days run a little better by reducing problems that cause irritation or inconvenience. Our people are full of great ideas about how to improve service, but with over 5,500 employees it can be challenging to find these ideas and make sure they get the right traction - so the best ones are explored and implemented. So we use campaigns to draw these ideas out and give them proper focus.

The Challenge Cup, is our annual competition for our people to submit business cases for their innovative ideas. The best ideas are allocated a sponsor from the senior leadership team who works closely with the employee to develop and implement their idea across our business.

This competition has already delivered significant benefits. The winner of the 2016 competition 'The Third Eye Drones' has saved over £0.75m by using drones to inspect assets in hazardous or inaccessible places. This innovation has reduced the cost and safety risks associated with asset inspections, and implementation has led us to create an in-house team to fly these drones.

In addition to asset inspections, we have also realised new opportunities, including the provision of aerial video footage of land for disposal prior to auction. This simple initiative typically increases land sale price by 20% - so our customers realise more value from it.

Our 2017 winners are showing equal promise.

Celebrating individual thinking – we nurture innovation from our front line

Some of our very best ideas come from the people who meet and serve our customers every day. Our annual Challenge Cup provides the opportunity for any of our people to put forward their ideas with the promise of executive sponsorship and funding to put winning concepts into action. Our 2017 winners:

Who:	Distribution operatives, Nottingham	Operations manager, Staverton	Team manager, Shropshire
Idea:	No disruption leak repair - Using a new to the market material to fix smaller leaks without requiring excavation.	Controlled bursting discs - installing calibrated weak spots on our network to find bursts quicker and minimise customer disruption.	Better pumping rules for waste – fitting timers on pumping stations to reduce activity during peak energy cost periods.

Our internal crowdsourcing campaigns **#BrightSparks**, are a simple, yet effective concept. Using our social networking platform Yammer, we pose innovation challenges, sponsored by a business area, requesting ideas to improve efficiency and customer service. Employees' ideas are triaged and then reviewed by business experts.

#brightsparks focuses our people on fixing service issues and driving efficiency

Beyond our targeted campaigns, we also encourage employees to email ideas to our innovation team. This increases the total number of ideas for evaluation by 25%. The email address is also available to people externally so anybody can easily share an innovative idea with us.

Sponsoring academic research

The cost of research to drive a step change in innovation, and access to live water company assets can be significant barriers for some suppliers. We therefore support research within universities.

This approach has led to a number of successful advances and product developments, and in many cases we're able to incorporate the outputs of academic research into our business processes without product development. For example, we've developed a model that's able to predict the metaldehyde concentration in rivers based on weather forecasts. This allows us to manage our abstraction, improve water quality and minimise investment in new treatment processes.

We believe we're the most successfully active UK water company in the external funding arena and house the only dedicated Innovation Funding team within the UK Water Industry. Through this team we've secured £0.84m of external funding and gained access to over £34m of additional research, through Horizon 2020 and Innovate UK funded projects. Our urban wastewater strategy is an example of a how we've utilised significant external funding to deliver innovation.

Crowd-sourcing ideas from across the globe

While we crowd-source ideas internally, we also look beyond our organisational boundaries to discover insights, ideas and knowledge. Using intermediaries has enabled access to a worldwide network with different backgrounds, experiences, knowledge and connections.

We work with the intermediary and the project team to develop a generic innovation question, which we then put to the intermediary network. By making the problem less specific to the water industry allows the network to explore where and how other industries may have come up with solutions to solve similar problems. For example, to help inform a recent strategy discussion for our Board, we asked:

"For this study we are interested in references disclosing, near to market and currently commercially available robotic solutions, which may be of use in the identification, analysis, maintenance or repair of self-contained, difficult to access structures, which may be above or below ground"

We received 110 responses – helping to provide much broader, forward thinking insight to inform our decision making.

We're still learning about the potential of this approach but it's proving a valuable way to get new, more diverse insights, at pace.

From innovation to 'business as usual'

Our 'communities of practice' are our network of subject matter experts - within our business and supply chain - who share a passion for innovation. We have over 40 communities with around 1,500 active participants. These communities are both a source of innovation and our innovation delivery network – helping to ensure new innovations are translated into the circa 70 standards we operate to.

And to continue driving our ambition to make our workforce the most technically skilled in the industry by 2020, we're committed to creating a centre of excellence – The Severn Trent Academy.

Our centre of excellence will showcase our technical brilliance and resilience, and bring all our learning resources and assets together into one integrated community, regardless of where they sit in our structure today. The Academy will help us ensure we have the right skills in place for deployment and optimisation of new technologies.

The future

We operate in a world of increasing complexity, uncertainty and rapid change. Climate change, evolving customer behaviours and disruptive technologies – to name a few - all present challenges and opportunities for our business. We need to be adaptive and agile in response.

Our five strategic ambitions to succeed in a changing world

To meet the evolving needs of our business in a rapidly changing world, we've restructured our innovation needs document around five strategic ambitions. These ambitions are the enablers of our wider company strategy – focusing on AMP7, 2045 and beyond - and endorsed by our Board. Because they're designed to inspire and challenge us - we've made them bold and ambitious.

The five ambitions also respond to our Water Forum (customer challenge group), who have challenged us to explore the potential of artificial intelligence to process data and generate real insights to serve our customers.

Our strategic ambitions focus on radical change

The ambitions are focused on radical change - to address the issues that challenge our sector and not only improve *how* we do what we currently do, but also fundamentally change *what* we do.

They build on the game-changing initiatives we've been working on over the last AMP. For example, we're already pioneering urban catchment with a flagship project near Redditch. This trial is designed to build our understanding of operational models, product recovery, enhancing resilience and carbon neutral wastewater operations. It's part of our ambition to create a carbon neutral business – enabled by turning all wastes into products. Our experimental effluent factory at our Spernal site has already led to:

- £80,000 opex savings per annum from optimised chemical and energy use;
- a 28 hour saving in operator time each week through process automation;
- £300,000 additional income per annum from combined heat and power (CHP) generation; and
- improved operator engagement and morale by reducing reactive work.

We know we're not alone in the challenges that face our business. So to date, we've visited over 30 companies world-wide from Levi Strauss to NASA to learn from the experience of others who are ahead of us. This insight is helping us to build our future innovation strategy.

PART 2: DRIVING INNOVATION IN THE SECTOR TO DELIVER BETTER OUTCOMES

Innovation is helping us to deliver the outcomes in our business plan today, and will continue to do so as we enter the next AMP.

For this section we've hand-picked a number of case studies from our wide variety of innovative work in this AMP. We think these best represent our forward thinking outlook and vision for AMP7 and beyond.

Case study 1: A UK water industry first - rapid bacteria detection technology

This case study showcases the benefits of using global scouting to find the best technologies from around the world as we seek solutions to one of the water sector's longest standing problems

Challenge

Our water treatment processes are designed to provide high quality drinking water.

The sector uses coliform bacteria to indicate an issue with drinking water quality. However, standard methods of detection typically take 18 to 24 hours for results following sampling – which is too slow for proactive interventions at water treatment works. We've therefore targeted finding real time bacteria detection measurement in our 'Innovation Needs' document to enable a proactive response.

Solution

We're testing and developing new processes to enable us to predict when an issue may occur at a water treatment works or in our network - to help us to respond rapidly.

Recognising the need for new technology, we've used worldwide scouting to explore possibilities. Following due diligence evaluation and independent testing, we selected four technologies for further evaluation on-site.

We're evaluating two online monitors which can take 16 to 24 samples a day and provide results 15 to 40 minutes after processing. We're the only water company in the UK to have secured these prototypes for trial. We're also evaluating two technologies which can be used for 'grab samples', with a potential application to support investigation into water treatment works failure and other operational issues.

Implementation

Our progress to date hasn't been without challenges. The two online monitoring systems were developed in countries where potable water is not routinely chlorinated, so we're working with the developing companies to transfer the technology to work in chlorinated water. This requires a different approach for each party but is potentially a very worthwhile development.

Following successful piloting at two of our sites, we will start deployment in late 2018, focusing on our key water treatment works that supply around six million of our eight million people.

An example of monitors installed on site

Benefits so far

Using flow cytometry we've developed a new lead measure of total cell counts for identifying the risk of failure – enabling us to address issues before they become a water supply problem.

We're able to measure the presence of coliforms - at the water treatment works itself- in a few hours, and our operators can quickly be made aware of potential contamination, allowing them to respond appropriately.

As the only water company actively evaluating predictive modelling tools, by working closely with the developers (performance testing the machines and software under different conditions), we're shaping the future look, feel and deployment of online monitors for future use within the sector.

And we're sharing our experiences with other companies and the DWI through the Water Industry Flow Cytometry Group. Our work is being presented at the American Water Works Association annual conference, the Water and Wastewater Treatment conference and has progressed to the penultimate round of the International Water Association Awards.

Case study 2: UK firsts for zero energy wastewater treatment in our rural communities

This case study demonstrates that innovation doesn't always have to be high-tech to give great benefits to our customers and communities – and we've saved up to 40% on totex

Challenge

In our 2015-20 business plan, we set ourselves the challenge to make a step change in how we deliver our wastewater services by 2050.

We wanted to find more sustainable approaches to delivering wastewater services in our smaller rural communities – at lower cost to our customers – but without compromising on the environmental compliance they expect. This means finding alternatives to capex and carbon intensive treatment processes. We therefore set out a challenge through our 'Innovation Needs' document to halve the totex of small wastewater treatment works.

Solution

We've worked with our supply chain to identify technologies and catchment management approaches that are capable of providing reliable treatment, require little operator intervention and facilitate community involvement.

Our first off-grid facultative pond system

Llys Rhysnant is our first off-grid wastewater treatment works. It delivers robust treatment to environmental discharge permit standard for a small catchment of 26 houses in Powys, Wales.

Treatment is delivered by a series of ponds, not conventional processes

Treatment is delivered by a series of three facultative ponds that operate without energy input or the need for regular desludging. Performance is observed by online flow and quality monitors powered by renewable energy to ensure the work is truly 'off-grid'.

This bespoke, community based solution also gives us the opportunity to engage our communities in their service - we're planning to install off-grid rainwater harvesting solutions including rain butts and rain water reuse systems for the local community which demonstrate the benefits of storm water control.

Using vertical flow reed beds

Hulland Ward is the UK's first two stage vertical flow reed bed system for municipal wastewater treatment. It delivers robust treatment against an ammonia permit standard for a village of 910 people in Derbyshire.

The reed beds minimise the carbon footprint of the works by operating with extremely low energy input and avoiding the need for regular desludging. The overall design will deliver a significant reduction in whole life costs when compared to the standard small population treatment works solution.

Vertical flow reed beds provide low carbon treatment

Implementation

Both Hulland Ward and Llys Rhysnant are undergoing long-term assessments in order for us to develop a thorough understanding of their performance envelope and operational risks. This assessment will allow our dedicated 'community of practice' to identify opportunities to optimise the design of potential passive treatment systems and embed the technologies in our design standards for deployment in our AMP7 capital programme.

Emerging opportunities

Our horizon scanning has also identified other opportunities including trial small scale anaerobic treatment systems, new technologies for nutrient removal at rural sites, and exploiting wetlands to achieve high quality effluents and enhance biodiversity. We'll be trialling them to explore their potential with a view to embedding them in design standards for AMP8.

Benefits so far

Adopting technologies that work well in other countries can cause operational challenges, so we've worked closely with Cranfield University and ARM, a local reed bed supply company, to redefine the overseas design guidance for vertical flow reed beds for UK conditions.

Our trials at Hulland Ward and Llys Rhysnant have revealed significant potential benefits for our customers and rural communities:

- lower whole life cost (potentially 40%);
- effluent quality monitors powered by renewable sources;
- natural resilience to mains power failure;
- very low need for operator intervention; and
- more opportunities for community engagement.

We've shared our experiences through the publication of the Hulland Ward reed bed system academic research and the presentation of the rural strategy design philosophy at industry conferences.

Our supply chain partners have gained first-hand experience of the design, construction and commissioning of these low carbon solutions and now have the capability to offer them as solutions for other clients.

Case study 3: Our urban test-bed: turning a bold strategic intent into reality and our waste into products

This case study showcases how we're progressively building upon our effluent factory at Redditch wastewater treatment works to turn it into a bio-refinery. It's attracting lots of match funding from Europe and will host Europe's first municipal mainstream anaerobic treatment plant

Challenge

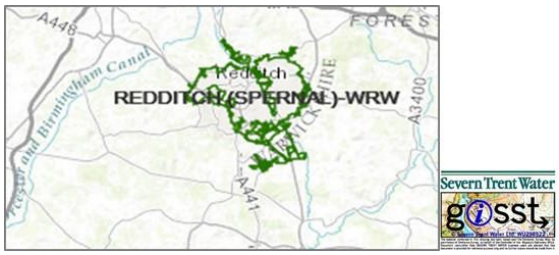
In our 2015-20 business plan we set out our vision to think about urban wastewater catchments in a radically different way.

We're developing integrated wastewater 'catchments' (as opposed to individual assets), enabling proactive interventions to reduce cost, improve customer experience and minimise environmental impact. We therefore set out a series of challenges in our 'Innovation Needs' document to turn waste into products and treat sewage with zero energy.

Solution

We're transforming our Spernal works near Redditch into a model area and test bed - trialling a series of interventions that optimise wastewater treatment from our customers' homes, through our network, treatment works and back to our rivers, to create an optimised production line.

A catchment rather than asset view



Building on our AMP5 pathfinding effluent factory trial during which we learnt more about how we could optimise treatment processes at our works, this multi-faceted trial focuses on an entire catchment.

Spernal – an effluent factory at the heart of the catchment

Implementation

Catchment factory dashboard

Rapid information about the condition of our works, network and wider catchment will allow more effective operational interventions and support the automation of remote assets. We're testing the value of near-real-time communication with remote assets and using third party data feeds, e.g. rainfall, to guide data needs for AMP7.

Active sewer management

We're developing tools based on hydraulic modelling and enhanced network monitoring to assess the benefits of active sewer management. This is a revolutionary new way of using real-time rainfall and sewer flow data to control assets in sewers to maximise their capacity in a storm.

Intelligent sewage pumping stations

We're evaluating the use of intelligent control components to optimise performance and facilitate the remote operation and automation of sewage pumping stations (see case study 8 for more information). Three inter-linked pumping stations have been equipped with intelligent panels and a library of enhanced control applications aimed at optimising power use and minimising reactive maintenance. These pumping stations also have a permanently open communication link with the treatment works to allow operators to monitor and control the stations in real-time.

Technology test-bed

We're so convinced that there's value in the circular economy we're investing £5.5m in a test bed facility to trial a pipeline of technologies that will develop our urban wastewater strategy.

Our initial focus will be on reducing the energy requirements of conventional wastewater treatment through the development of anaerobic mainstream treatment processes and the evaluation of enhanced primary treatment options.

Anaerobic processes drastically reduce both energy demand and sludge production compared to traditional aerobic treatment processes and could potentially enable our wastewater treatment plants to be transformed - from energy and resource-consuming facilities - to production plants and bio-refineries.

Anaerobic treatment is used at full scale in the tropics but has yet to be established in a temperate climate. Our ambition to be the first to demonstrate anaerobic mainstream treatment in the EU has helped us secure funding from the European Union's Horizon 2020 £8.9m research and innovation programme 'NextGen' under grant agreement number 776541. NextGen will provide £453,000 of direct funding to help us deliver a demonstration scale anaerobic membrane bioreactor at Spernal.

Full scale anaerobic treatment plant – Onca, Brazil

To support the development of our technology pipeline for our test bed, we've also successfully become part of the European Union's Horizon 2020 £7.9m research programme 'Smart Plant' and received funding under grant agreement number 690323. Smart Plant is pilot testing resource recovery technologies for cellulose and bioplastics.

We recognise that a successful strategy is reliant on developing markets for the products created at our bio-refineries. To help us understand the potential value of various constituent elements of waste, we've become a partner in the Interreg North-West Europe project 'WOW!' a £5.7m research programme developing markets for products from waste. The programme will provide £184,000 of direct funding to allow us to produce resource market assessment tools.

Our engagement with the EU funding programmes allows us to share our experience and know-how with a wide range of research institutions and suppliers and learn from them in return.

Benefits so far

By establishing a model area to assess new technologies and ways of working, we've been able to increase our collaboration with a wide range of technology providers and universities. Our approach has allowed them to demonstrate their innovations or deliver their research in an appropriate setting, supported by an experienced cross functional delivery group.

Looking forward, we believe the test bed will accelerate this collaborative approach to innovation and we will secure benefits from the pipeline of technologies that systematically turns wastewater into commercial products.

Our Spernal effluent factory has so far led to:

- £80,000 opex savings per annum from optimised chemical and energy use;
- a 28 hour saving in operator time each week through process automation;
- £300,000 additional income per annum from combined heat and power (CHP) generation; and
- improved operator engagement and morale by reducing reactive work.

We believe this is the most ambitious wastewater experiment in the UK and will not only build on our strong track record, but also – by evidencing the potential to treat waste as a product - contribute to a new strategic direction for our sector.

Case study 4: Unlocking the potential of drones (and our people)

This case study showcases that the best ideas – with the right momentum behind them – come from our people

Challenge

We want to maintain our assets and ensure they remain resilient for many years to come. However, with a vast asset base and wide-ranging operations, it can be challenging (and sometimes hazardous) for us to get a full picture.

Solution

Our 2016 Challenge Cup – an internal competition which seeks the best innovative ideas from our people - championed using drones to get a new perspective on our assets – the 'Third Eye'. While drone technology is now well established, their use in the water industry in 2016 – wasn't.

Building on a concept and business case proposed by one of our capital assurance technicians, we established a new dedicated team of drone pilots – which we believe is a first for a UK water company. They use industry leading technology including a combination of photometric and thermal sensors to look at our assets differently.

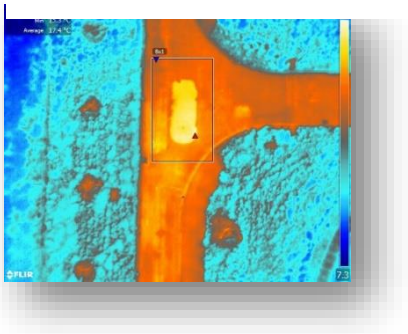
Implementation

We've already exploited wide-ranging uses for our drones.

Improved leak detection

Thermography enables us to detect subtle temperature differences in water and waste compared to the surrounding environment and allows us to detect leaks at a much quicker rate.

Thermal imaging

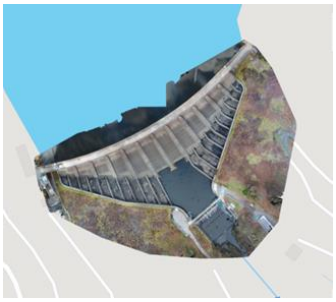


Surveying our assets

In a way similar to Google Earth, we can survey our assets using drone imagery and convert this footage into 3D models to use for asset inspection – reducing risk of failure and improving asset life through proactive maintenance.

And drones enable better information management (BIM) - 3D models, 360^0 imagery, e-learning, virtual reality and artificial Intelligence are all achievable using drone imagery when combined with other software. By using these, we improve our knowledge bank, records, capability and succession planning; all leading to better customer service and more efficient operations.

BIM aided by drones



Benefits so far

With an investment of £150,000, we've unlocked £750,000 of financial benefits to date.

But we believe the potential of drones is much greater – particularly when combined with other technologies. We're working in collaboration with Cranfield University to learn how other global industries are getting the best out of using drones and satellite data.

The idea has demonstrated to our people the importance of innovation – with other UK utilities now seeking to understand how they can better utilise drones as part of their operations.

Case study 5: Targeting previously invisible pressure waves to reduce bursts by 15%

This case study showcases a UK first –applying D.Eng research to operational decision making to tackle industry wide issues

Challenge

Pressure transient waves are short-lived pressure spikes in water pipes. These transients are generated by sudden, significant changes in the velocity of flow in the network caused by the operation of valves and pumps or large increases in customer demand for water. Research indicates they are responsible for 15-20% of bursts on our network.

Solution

The pilot project aims to develop and implement a standard control solution to improve start/stop operations at pumping stations to eliminate pressure transient waves.

During 2018, we're rolling out our solution to 21 of our sites in Nottinghamshire to significantly reduce transients generated from pumping station operations.

More effective control settings for pump start/stop operations

Implementation

This work was instigated via an Eng.D funding programme with Imperial College, and has evolved from the development of a model to prove a relationship between transient waves and bursts.

Through a start-up company originating from Imperial College London, we aim to develop a model to enable even better quantification and understanding of the relationship between dynamic pressure variability and bursts. This will allow us to assess risk and predict the reduction in burst rates at each site. It's a collaboration that has driven industry leading understanding of pressure variability and bursts and now implementing innovative solutions to deliver operational benefits.

Benefits so far

We've already seen benefits at one of our pumping stations. Following a £15,000 investment in pump improvements, pressure transient occurrences have been eliminated, resulting in approximately 70% reduction in burst rate since 2015. The avoidance of repairs translates to an opex saving of £60,000 per year, giving a three month return on investment and less disruption to customers. We're standardising our approach following the outcome of the pilot, and aim to roll the solution out across our region.

We've also used our increased understanding of the long term fatigue effects of pressure transients in our modelling to improve efficiencies in mains replacement

Case study 6: An international award winning approach and world first: using real time satellite and rainfall data to predict pesticide levels in rivers – which we believe could result in a £30m totex saving

This case study demonstrates how we've combined PhD research with other initiatives to turn a big problem into a manageable one

Challenge

Metaldehyde is a pesticide found in slug pellets that is often used to protect crops such as oilseed rape. During heavy rainfall, metaldehyde can be washed directly into rivers, causing spikes in concentration. At higher concentrations, conventional water treatment processes, such as using activated carbon for pesticide removal, are not effective. So unless we find alternatives, we'll need costly upgrades to water treatment works to remove the pesticide.

Solution

We've been investigating removal of metaldehyde from the catchment and at the water treatment works. Through research and collaborative industry groups, we've:

- implemented a series of local catchment based initiatives to increase engagement, promote best practice and assess the impact of farm-based technological compliance solutions;
- built our knowledge and understanding of our catchment area, identifying potential hotspots, new stakeholders and future catchment opportunities;
- optimised our abstraction management within existing licence constraints;
- developed and trialled online monitoring technology; and
- assessed conventional treatment capabilities and explored innovative treatment solutions that could achieve consistent and cost effective metaldehyde removal.

Implementation

To date we've focused on 12 water treatment works in catchments at high risk of metaldehyde contamination.

Developing satellite catchment management

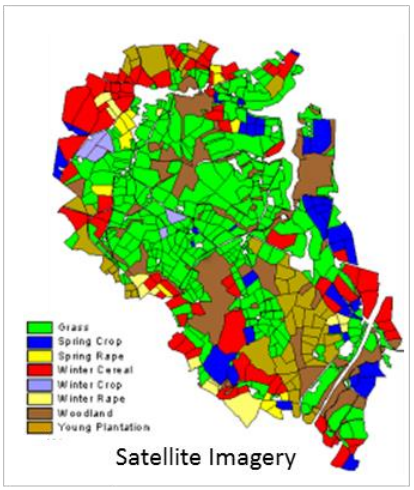
We've played a leading role in several initiatives to reduce the concentration of metaldehyde in rivers. The first of these was the creation of a water industry liaison group to work with farmers and metaldehyde manufactures to develop and ensure best practice for the use of slug pellets containing metaldehyde.

As part of this work, we pioneered the use of satellite imagery to help guide our catchment management teams to high-risk areas within our 19,000km^2 catchment. This has helped us work with farmers to:

- reduce application rates;
- improve the timing of slug pellet application in high risk areas; and
- trial the use of metaldehyde-free slug pellets.

Our approach has successfully led to significant reductions in metaldehyde concentration. We've been at the forefront of our industry with this technology, and several other water companies have followed suit and adopted this method.

Using satellite imagery to find high risk areas

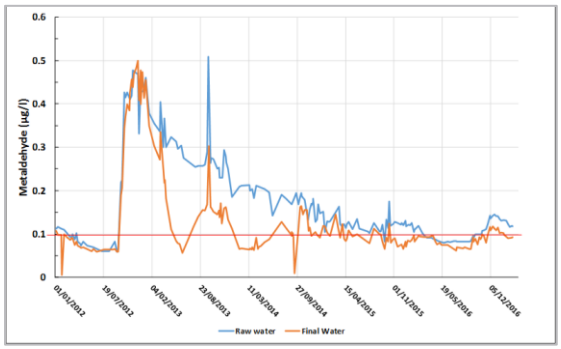


Industry collaboration to develop novel treatment processes

We've also worked with other water companies to trial a range of treatment solutions that could be used to enhance our water treatment sites. This has included trials of advanced oxidation processes (AOP) which are normally used for industrial waste treatment.

During AMP6, we screened several potential technologies and selected the most promising options for extensive pilot plant trials at a water treatment works in Warwickshire. These trials included AOP options using high doses of UV light, hydrogen peroxide and ozone. The trials successfully proved the technology's viability, while also highlighting there is more to learn about the link between the by-products produced and the organics present in the source water.

Trialling different processes to reduce metaldehyde



In addition, we also trialled a novel form of activated carbon made from polymers - Saratech. This material is normally used in chemical warfare suits and has been specifically reformulated for use in water treatment. The trial identified the Saratech media is much more effective at removing metaldehyde than conventional carbon treatment.

As this is an industry-wide issue, we collaborated on the Saratech trial with five other water companies. This work has enabled us to develop detailed forecasts for the cost of each treatment process at each of our water treatment works.

We've highlighted that for AOP processes, the capital investment required is heavily influenced by the initial concentration of metaldehyde – halving the concentration of metaldehyde will reduce the capital investment required by more than 80%.

Creation of a metaldehyde prediction model, potentially saving over £30m totex within our region alone

To complement the investigations into treatment solutions, we've been working to improve smart abstraction management through academic research with the University of Sheffield.

Together, we've developed the world's first metaldehyde prediction model.

This ground-breaking model predicts the concentration of metaldehyde in rivers up to 48 hours in advance, enabling us to suspend abstraction and avoid failing the water quality standard for pesticides.

The model takes existing data sources, including satellite imagery of crop types, soil characteristics and topography, and combined with radar rainfall data, predicts how the concentration of metaldehyde in our rivers will change.

For most catchments, this approach will enable us to halve the concentration of metaldehyde – avoiding potential water quality standard failures and reducing the investment required in treatment solutions. If we are required to build more assets in the future, the estimated benefit would be a capex reduction greater than £30m and an opex reduction of £1m per annum.

Defra intend to consult on a targeted ban on metaldehyde to complement ongoing catchment management and voluntary stewardship. We will continue to focus on developing catchment-based solutions and will incorporate this into our approach.

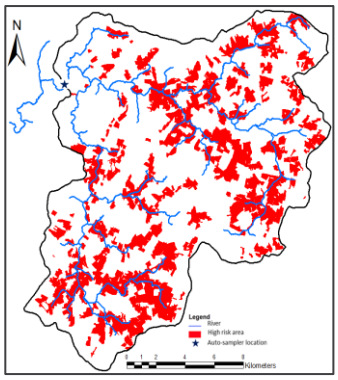
We're also developing the option to integrate this model with our telemetry systems, enabling us to fully automate abstraction management for metaldehyde; the system will automatically collect and analyse data, and control our abstraction without requiring human intervention.

Benefits so far

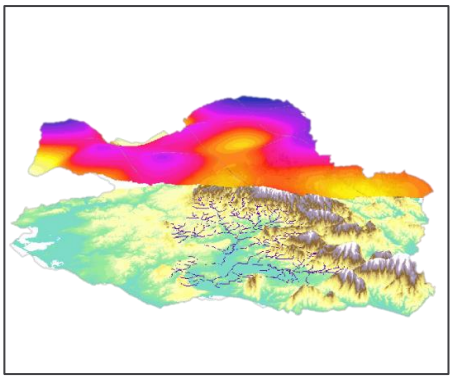
We're sharing the outputs of this ground-breaking research with both the UK and international water industry including publishing detailed technical papers in leading research journals such as the Journal of Hydrology and the Water Research Journal.

We've also highlighted our success and the benefits of this unique approach through the Innovation Project Awards for the International Water Association, enabling us to share our findings with leading technical practitioners around the world. Following some fierce competition – 160 entries from 45 countries – our entry was ranked in the top three for Category M: Smart Systems and the Digital Water Economy - a result we're delighted with.

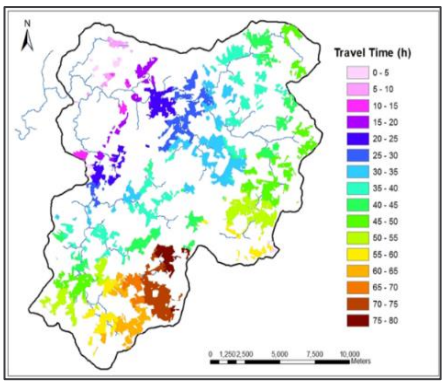
Metaldehyde prediction model



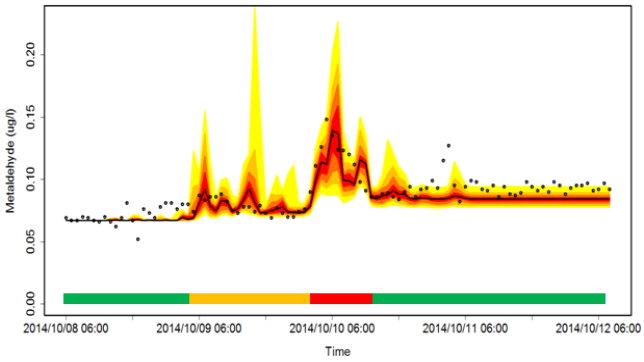
High risk areas based on crops grown, soil type and topography



Radar rainfall data to predict surface runoff



Travel time from each high risk area based on rainfall data and river flow



Model output showing predicted metaldehyde concentration to inform when abstraction should be suspended

Source: PhD Thesis, Dr Alemayehu Asfaw, 'Under development of real-time surface water abstraction

Case study 7: Tackling discoloured water at source

This case study highlights that by pushing the boundaries around manganese removal and exploring the link between manganese and customer complaints, we can directly benefit our customers' daily lives

Challenge

Providing water that is both safe and good to drink is our customers' most fundamental requirement. And while discoloured water may be safe to drink, it can cause concern for customers and detract from their enjoyment of our product.

Discolouration occurs due to small iron particles accumulating in water. Under normal circumstances, accumulated iron will remain attached to the pipe wall. However, when water flow increases above the normal level, deposits can be disturbed, giving rise to visibly discoloured water. The sources of these deposits are the accumulation of low levels of iron in water leaving water treatment works and the degradation of unlined cast iron pipes.

We therefore included a specific challenge in our 2015 'Innovation Needs' document to reduce discoloration.

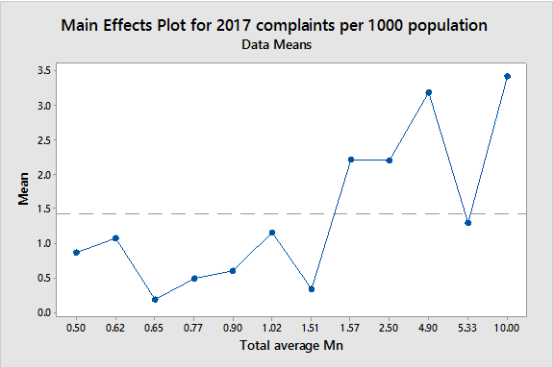
Traditionally, we've attempted to reduce complaints by replacing or relining water mains and by mains cleaning programmes. However, despite significant investment, complaint levels have not significantly improved, as materials continue to be deposited after cleaning. Research from the University of Sheffield has shown it only takes 12 to 24 months for a pipe to begin depositing to pre-cleaning levels.

Furthermore, analysis of industry-wide complaints suggests the presence of cast iron mains alone cannot account for all discoloration. For example, Thames Water has the highest percentage of unlined cast iron mains and the lowest rate of discoloured water complaints, suggesting the sources of water is a strong contributory factor. Our focus therefore has been at treatment works.

Solution

We've investigated a potential link between levels of manganese and discoloured water complaints, and whether manganese entering the distribution system catalyses the build-up of iron deposits on pipe walls. Our analysis found a strong correlation between manganese and discolouration complaints.

Correlation between manganese levels (ug/l) and discolouration complaints



After further investigation, we identified natural variations in the amount of manganese present in raw water and in lime used for pH control at our water treatment works. We've therefore trialled low manganese lime at four sites including our two largest treatment works

Our investigation also revealed that for most sites:

- the major source of manganese was a by-product in our coagulant (ferric sulphate); and
- manganese was being removed by adsorption and oxidation processes in our existing sand filters.

Implementation

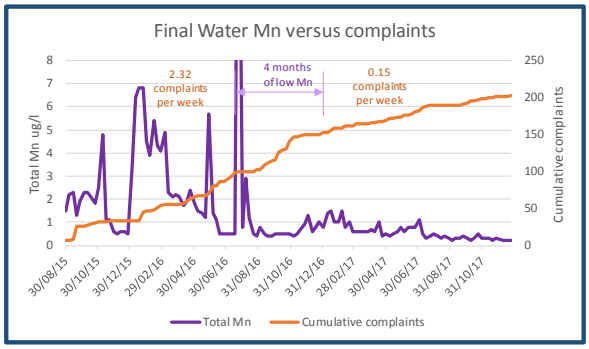
We've built a pilot plant to inform how to optimise manganese removal using existing processes, and monitored the impact on complaints.

Benefits so far

These changes have significantly reduced the amount of manganese entering our network resulting in a reduction in complaints, our ODI for number of drinking water quality complaints and indirectly our ODI for customer service satisfaction.

We're continuing to assess the effect of manganese reduction at the pilot sites. Roll out to further sites should then follow and should lead to significant reductions in customer complaints.

Correlating manganese reductions to complaints



To date, we've:

- reduced water complaints for discolouration at our trial plant from an average of 2.32 per week to 0.15 per week within four months of reducing manganese levels;
- negated nearly 1,500 complaints per year in the Birmingham area water treatment supply zone;
- made savings to date across all sites amounting to over £1.8m; and
- contributed to the 12% reduction outturn for our water quality complaints ODI for 2017.

Case study 8: Home grown talent results in intelligent sewage pumping station control panels - creating a possible UK first deluge detection network.

This case study showcases home-grown talent working in collaboration with our supply chain to develop a revolutionary patent pending technology

Challenge

We wanted to find a better way to control our pumping stations to drive more opex efficiency - through enhanced automation and optimised performance - without any increase in capex.

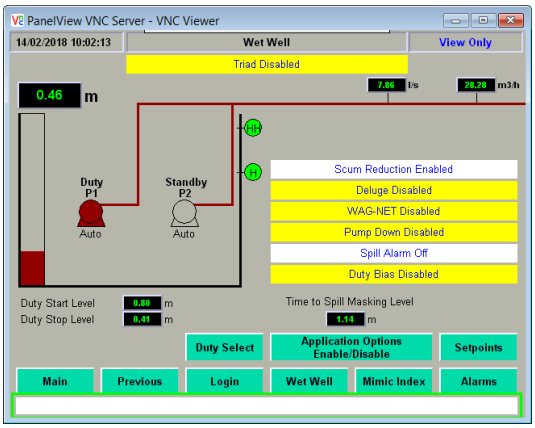
Solution

We've supported one of our graduate engineers, in a collaborative project with our supply chain partners.

Intelligent design

We are investing £225,000 in the trial of three intelligent sewage pumping station panels in our wastewater model area. Three inter-linked pumping stations have been equipped with intelligent panels and associated applications, including new flow meters and secure wireless communication transmitters. We're now entering a 6 to 12 month evaluation stage in order to test the functionality of the panels before creating a roll-out plan.

Human-machine interface connected to Ballard Panels



We're also trialling a new, 'always open' secure communication to allow operators to monitor and control the stations remotely in real-time. This is already being used effectively to avoid a number of unnecessary call outs.

Overall, this projects aims to show the benefits of constructing a linked catchment of pumping stations, working together to optimise flows in all weather conditions, requiring minimal reactive operator interventions.

Implementation

The panels are already showing benefits with:

- optimised energy usage;
- effective operational interventions;
- flood prevention;
- pro-active asset maintenance; and
- real-time data visualisation.

The combination of intelligent components and new control applications has allowed us to apply for a patent, generating the potential for future revenue, should the approach be licensed by others.

Benefits so far

A connected network

Using intelligent pumping stations, it will be possible to implement a catchment approach to network utilisation and performance. We want to be able to visualise real-time data from all pumping stations in the catchment, in order to make control proactive decisions which avoid flooding and pollution incidents. These decisions could be generated from machine learning and implemented remotely to further reduce time, cost and error.

Case study 9: We invested more than £4m in a sector leading phosphorus removal test bed and have delivered £13.6m of totex efficiency so far - with more to come

This case study showcases the scale of investment we're making to develop enhanced phosphorus removal solutions, including chemical free technologies

Challenge

Phosphorus from our effluent can cause eutrophication in rivers, which in turn can harm aquatic wildlife. To protect waterbodies, the Water Framework Directive (WFD) requires wastewater companies to meet much tighter phosphorus limits than we've had in the past (0.5mg/l).

In previous AMPs, the industry has delivered these improvements using conventional treatment processes which are both capital and energy intensive. We want a more efficient approach for the benefit of our customers and the environment.

And we also wanted to further drive down the phosphorus treatment limits that could be achieved – giving us more flexibility about how we achieve WFD standards in catchments.

Solution

Working closely with our academic research partners at Cranfield University and our design and construction supply chain, we've invested £4m in a state of the art test rig at our Packington wastewater treatment works to trial a variety of innovative new phosphorus removal technologies. The Packington trial complemented a national low phosphorus trial which followed a couple of years later. Starting early enabled us to implement innovative phosphorus solutions in AMP6.

Packington test bed during construction

Implementation

The range of new technologies we're trialling are already realising benefits - and will continue to do so during AMP7.

Magnetite ballasted coagulation process (CoMag).

This process combines a coagulant, a magnetite ballast and a polymer, to produce a weighted precipitate that settles very quickly and effectively. The trial was successful and showed potential for delivering very low phosphorus levels. As a result we're already installing the process at Finham, one of our largest wastewater treatment works - to achieve a very tight phosphorus limit of 0.22mg/l.

Installing a CoMag solution, over a conventional method has resulted in a totex saving of £8.7m and a 218% return on investment on one scheme alone.

CoMag pilot plant at Packington

We're also building a BioMag plant (a closely related process from the same technology provider) in AMP6. The CoMag process has been included as one of our standard design solutions and is particularly suitable for large works, with very tight phosphorus limits.

Pile cloth media filters (Mecana)

This technology uses a similar method for phosphorus removal as traditional sand filters. However, this innovative cloth filter is very fine and can change weave, making it a more effective alternative, as well as using less energy.

We're installing pile cloth filters at ten sites in AMP6 and anticipate a wide-scale roll-out in AMP7. These filters provide a very effective solids removal process and are included in our design manual as a low totex solution for tight phosphorus limits on small to medium sized works.

For example installing these filters at Redmile wastewater treatment works, a small works serving a population of less than 1000 with a new phosphorus permit of 0.5 mg/l delivers an AMP6 totex efficiency of £209,000 over the conventional solution.

Mecana pilot plant at Packington

Iron dosed tertiary membrane filtration

This technology uses ultra-filtration iron-dosed membranes to ensure virtually all solids are removed from the effluent, delivering extremely low phosphorus levels. The trial at Packington demonstrated the process is capable of meeting very low phosphorus permits (of 0.1 mg/l and below). However, the totex was high, and we've found even more cost effective solutions for AMP6 permits and those expected in AMP7.

Reactive media reedbeds

This replaces conventional media (gravel) with a media that reacts with the phosphorus and then filters it out. This process would be ideal for small treatment works where delivering and storing chemicals can be problematic. The steel slag media evaluated at Packington is a by-product of the steel industry. Although the process was effective at removing phosphorus, the pH of the effluent was raised to unacceptable levels. We've continued to develop and evaluate alternative media, for example apatite, a natural rock media with an affinity for phosphorus. We have plans to run further trials this AMP with a view to full scale roll-out in AMP7 if successful.

Reactive media reed bed at Packington

Immobilised algal bioreactor

This uses algae to remove phosphorus (and ammonia) rather than using chemicals such as iron. The method offers a more sustainable approach to meeting the WFD challenge. This novel (world first) approach encapsulates algae in a bead, significantly reducing the energy required to separate the algae from the treated effluent. Further development is required to increase the readiness of the technology before we can consider its full scale implementation.

Encapsulated algal beads

Nano-particle embedded ion exchange

One of the novel technologies we've been evaluating is an ion exchange process, which removes the phosphorus from waste by adsorbing it onto a media bed, removing the need to dose with chemicals. The media bed can be regenerated, allowing the phosphorus to be recovered in the form of a useful mineral (calcium phosphate). If this process is successfully implemented it has the potential to reduce the UK's reliance on importing mined natural phosphorus rock. Although the ion exchange/adsorption element of the technology is well developed, further work is required to optimise the regenerant clean-up and phosphorus recovery. Cost modelling indicates that the process could be very cost effective if we're able to overcome the technical issues.

Nano-particle embedded ion exchange at Packington

Benefits so far

These trials have enabled us to roll out a number of the technologies to our sites, delivering AMP6 totex efficiencies of over £13.6m. For AMP7 we envisage similar totex savings. We're the only water company undertaking phosphorus removal trials on this scale and for this duration, testing some products that aren't commercially available.

Throughout the trial, we've hosted numerous visits by the Environment Agency, local MPs, Natural England, catchment sensitive farming groups, water companies and interested stakeholders. We've also shared non-commercially sensitive information with the sector.

Case study 10: Reducing our environmental impact and driving efficiencies through Nereda®

This case study showcases how we provide the most cost effective and innovative process treatment solutions by 'fast-following' others in the industry to meet WFD objectives

Challenge

To deliver the objectives of the WFD we're required to meet some very stringent discharge permit limits for phosphate and ammonia. The challenge is to do this with the best possible totex solution and reduce the environmental impact of achieving these permits.

We've identified three sites (Radcliffe on Trent, Walsall Wood and Barston) in our AMP6 programme where we're able to use the Nereda process to achieve ammonia permits down to 1 mg/l and total phosphorus (T-P) limits down to 0.2 mg/l.

Demonstration of Nereda settlement

Solution

Nereda is a granular activated sludge batch process. Developed in Holland between 1998-2008, it has sixteen reference sites throughout Europe, with two sites recently commissioned in the UK. The granular sludge in the Nereda process is a complex community of microorganisms that are able to simultaneously deliver biological phosphate and ammonia removal within the same reactor vessel.

Conventional biological phosphate removal requires separate aerobic, anoxic and anaerobic zones within an activated sludge treatment plant, with ammonia removal occurring within the aerobic stage. With the Nereda process, these different conditions exist within the granular activated sludge particles themselves, removing the need for the separate treatment zones.

Radcliffe on Trent will be utilising Nereda as the sole secondary treatment process to achieve its phosphorus permit of 2 mg/l. Walsall Wood and Barston will have an additional tertiary treatment stage to further reduce T-P to achieve the tighter 0.5 mg/l & 0.2 mg/l e T-P permits respectively.

Due to the nature of the batch process, ammonia levels are achievable down to limits of detection, providing the reactors are sized accordingly.

Implementation

The Nereda plant at Barston wastewater treatment works is due to be commissioned in March 2019. Due to the extremely high standard of treatment achievable with the Nerada process, we're taking the opportunity to reconfigure the upstream sewer system to divert additional flows to Barston. Historically, part of the Barston catchment was diverted to Coleshill sewage works to protect a downstream potable water supply abstraction at a Warwickshire water treatment works. Diverting this flow back to Barston will free up capacity at Coleshill to cater for substantial new developments planned around the NEC and also help to safeguard the deployable output at Whitacre. The Nereda plant, coupled with a two stage, chemically dosed tertiary treatment plant will deliver compliance with the very stringent permit limits of 0.2mg/l T-P and 1.0 mg/l ammonia.

Walsall Wood wastewater treatment works is due to be commissioned in January 2019. The new plant will deliver compliance with tight new permit limits of 0.5 T-P and an ammonia-N permit of 1.9 mg/l.

It's expected that both of these Nereda plants will achieve effluent concentrations below the final effluent ammonia permits, and remove phosphorus down to concentrations of 1 mg/l. The addition of metal salt dosed tertiary treatment plants will then achieve the final phosphorus removal required to achieve the T-P permits for both works.

Radcliffe on Trent wastewater treatment works is the final works to be commissioned and construction is due to start May 2019. As part of this project we will be taking the opportunity to rationalise our asset base by

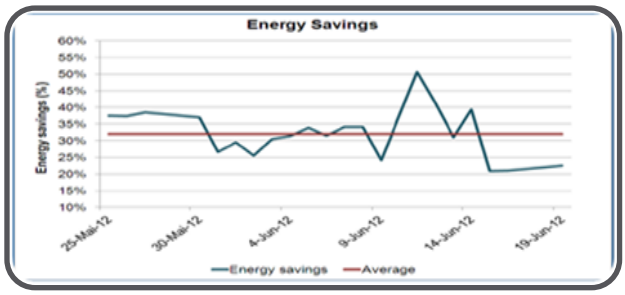
closing the nearby wastewater treatment works at Cotgrave, effectively doubling the size of Radcliffe. This rationalisation removes the need to upgrade treatment at Cotgrave, which would otherwise have been required to deliver the desired WFD outcome. The Nereda process will deliver compliance with a 2mg/l T-P permit limit without the need for any additional chemical treatment. This rationalisation has also achieved savings of approximately £1.5m in capex.

Benefits so far

Nereda can generate the following benefits:

- a reduced footprint (up to 50% reduction);
- reduced energy costs (40% reduction expected) in comparison to standard activated sludge plant (ASP) designs; and
- achieve T-P permits of down to 1 mg/l through enhanced biological phosphorus removal without the need for additional chemical treatment.

Typical energy saving against comparable ASP



Case study 11: A balancing act – energy flexibility delivers £1m benefit – and wins us the 2018 Water Industry Award for energy and carbon initiative of the year

We help National Grid balance supply and demand, so electricity is available for everybody. We can now provide flexible capacity, equivalent to the power demand of a town the size of Stafford

Challenge

The Climate Change Act requires the UK to reduce its greenhouse gas emissions by 80% by 2050. The water sector is a large consumer of energy and emitter of carbon - much of which is associated with electricity usage. We need to adapt and drive change to support long term sustainability.

We're aiming to deliver over 20MW of demand side flexibility capacity by 2020, helping to balance electricity supply and demand on the National Grid.

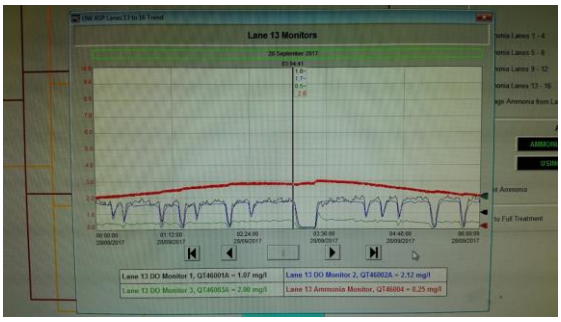
If we can help provide flexible capacity, peaking power stations can be displaced, helping to create a cleaner, efficient, more secure and cheaper electricity network. This will drive extra value from our assets, helping us deliver the lowest possible bills for our customers.

Solution

Our equipment, such as pumps, motors and blowers, can automatically adjust their electricity use second-by-second without affecting processes. This flexibility enables the efficient balancing of electricity supply and demand, creating our own virtual power plant, and allows better control of our plants and offers varied generation sources.

The equipment uses frequency signals to immediately indicate the balance between electricity supply and demand, which the National Grid maintains at 50Hz. This happens at live operational sites, without any impact on processes.

Where frequency response is active, teams can track activity in real time, although the operational impact of switching is barely noticeable



The technology also gives us far greater visibility of how our assets are performing in real time. We can use this insight to innovatively optimise our sites for the future – pre-empting maintenance issues, improving resilience, and thinking smarter about how we can integrate other technologies, such as renewable energy and battery storage. We are, for example, currently undertaking feasibility for the integration of electric vehicles and our first dedicated battery into our flexible energy portfolio.

Implementation

The programme has been delivered in two phases, the initial phase trialled demand side response systems at a site to prove the technology works and provide confidence when rolling out across the region. Working with aggregators, we used their knowledge and data, combined with our own process risk understanding, to give confidence to our operational teams. We also worked closely with National Grid and Power Responsive to develop our plans and strategy in line with their system needs and product roadmap. The trial took place at our Spernal model site, and at a larger site with standby generation in Gloucester.

The second phase delivered a wider roll-out to some of our largest and highest energy-consuming operational sites. We've done this through a small dedicated team of our people, secondees from our supply chain, alongside design and installation work undertaken by our systems integration partners.

Benefits so far

In the first phase, to March 2018, we've delivered:

- 14MW of flexibility;
- annual benefits of approximately £1m; and
- minimised exposure to market volatility.

Furthermore, we've driven value from otherwise idle equipment and improved the resilience of our standby generators – which while installed to a mechanically high standard, were manually operated. And we've identified legacy control issues which may have compromised emergency power resilience. Following rectification, the reliability of the engines are now significantly higher. We've since applied lessons learned to improve our other sites.

The increased data insight enables us to identify further efficiency opportunities as we're able to see in much more detail our energy usage across our sites, thus enabling us to constructively challenge accepted practice.

The next phase of this work is to widen the flexible asset base to include storage and renewables sources by the end of AMP6.

Case study 12: A global water industry first – online zeta potential for coagulation control

This case study showcases the benefits of working with manufacturers to develop technologies from other sectors, providing a solution to significant challenges within the water sector.

Challenge

Our water treatment processes are designed to ensure we can provide high quality drinking water for our customers.

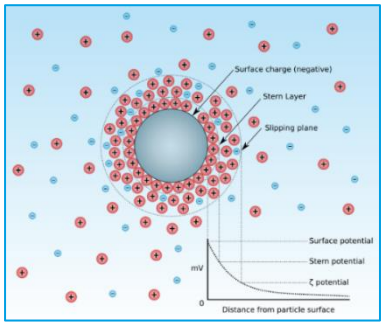
We spend around £3m a year on coagulants such as ferric sulphate, which help remove organic compounds, particles and bacteria. It's vital that we set the correct dosing for coagulation to align with a wide range of water quality measures, and ensure the treatment process is operated effectively.

Solution

We've previously utilised 'zeta potential' as an alternative approach to optimise the chemistry of our coagulation process. This approach uses a specialised instrument to measure the electrical charge on particles as they react with the coagulants in order to determine the most appropriate dose rate needed. We were early adopters of this technology from the pharmaceutical sector, having routinely used it at a number of our treatment sites.

Our innovative approach was to work with the manufacturer, Malvern Panalytical, to automate the process, so the instrument could provide a constant stream of data, rather than spot samples, to give us more efficient and up-to-date information to increase dose optimisation.

Dose optimisation



Source: Malvern Panalytical

Implementation

Following an extensive collaborative development process, our manufacturer launched the Zetasizer WT, the world's first online system for measuring zeta potential. During AMP6 we've installed these instruments at a number of our treatment sites, and shared our water treatment technology advancement with colleagues within the UK and internationally.

World's first online Zeta measurement system

Source: Malvern Panalytical

Benefits

During AMP7 we will continue to use the Zetasizer WT at key sites to optimise coagulation control. This will deliver benefits by improving water quality, increase the robustness of our treatment processes and reduce average coagulant consumption by 5% per annum.

We've shared the benefits of our approach with the water industry at conferences in the UK and Europe.

And the industry's recognition of the innovation has culminated in it winning the 2018 Water Industry Award for most innovative use of an existing technology.

Case study 13: Possibly the most ambitious wastewater experiment in the UK - recovering valuable resources from waste

This case study illustrates how we're driving to be at the forefront of the emerging circular economy; our industry leading research has been supported financially and technically through collaboration with partners across Europe

Challenge

The linear economic model where we 'take, make and dispose' of things is not sustainable. It relies on large quantities of cheap easily accessible materials and energy. A circular economy keeps resources in use for as long as possible and then recovers and regenerates products and materials at the end of their service life.

The water sector can play an important role in the emerging circular economy. As part of the water cycle, a large amount of 'waste' water is returned to us from our customers. This is full of potentially valuable recoverable or re-generable materials, which we can either use or sell.

Solution

Our PR14 business plan recognised the need to redefine our approach to wastewater treatment in order to embrace the circular economy.

We've worked closely with academic partners to identify existing technologies and technology gaps to help address our ambition to establish resource recovery factories – our urban strategy (see case study 3 for more details). Our ambition has helped secure access to European research and funding programmes including:

- Horizon 2020 SMART Plant – developing low carbon material recovery technologies to upgrade wastewater treatment plants
- Horizon 2020 NextGen – evaluating and championing circular economy solutions and systems in the water sector; and
- Interreg WOW! – developing markets for products from waste.

European research and funding programmes

SMART-Plant

Supported by the Horizon 2020 Framework Programme of the European Union

Interreg North-West Europe WOW! European Regional Development Fund

Bio-plastic recovery pilot plant, Treviso, Italy (SMART plant)

Implementation

We've been operating full scale struvite (an effective slow release phosphate fertilizer) recovery at Stoke Bardolph wastewater treatment works since 2015 and this has confirmed the potential for recovering valuable materials from wastewater.

Struvite recovered at Stoke Bardolph

Our low phosphorus demonstration site at Packington wastewater treatment works has been used to start the evaluation of technologies including encapsulated algal beads and ion exchange which will facilitate the recovery of phosphorus and nitrogen.

We're also working with academic partners, EU programmes and our supply chains to establish a schedule of trials to develop the processes needed to recover nutrients, bio-plastics, lipids, cellulose and even protein from wastewater.

To facilitate this, we've invested £5.5m in an industry leading innovation test bed at Spernal wastewater treatment works. The test bed will facilitate the assessment of new processes and allow us to develop robust process design standards and understand the operational risks and requirements for the novel technologies and flow sheets.

Benefits

We've learnt valuable lessons from our experience of struvite recovery and recognise the need to develop markets for the products we produce.

To date, we've successfully secured access to £34m of external research funding and £950,000 of direct grant income as a result of our strategic intent to drive a circular economy model for the water sector, and to develop products from waste.

Case study 14: Targeting the build-up of fats, oils and greases (FOG) with a UK first solution

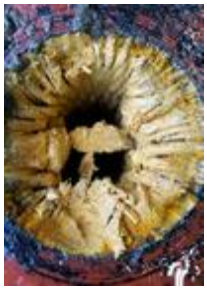
This case study demonstrates how we're using bio-augmentation to tackle sewer blockages - helping protect our customers and our network

Challenge

Our customers tell us that sewer flooding is one of the worst service failures they could experience. Discharge of fats, oils and greases (FOG) into the sewer network poses a major challenge for the water industry. It's estimated that around 55% of the 45,000 sewer blockages we incur every year are caused by FOG related issues.

FOG is a waste product generated by food processing sites, food service establishments and residential populations which is discharged into the sewer after food preparation, washing up and cleaning. It accumulates and forms a solidified build-up on pipe walls, mixes with other waste for example, wipes, to form 'fatbergs' – which are large insoluble masses.

FOG accumulations blocking pipework



FOG accumulation and fatbergs reduce the available space in sewer pipes and cause blockages in our network. It also impacts the efficiency of pumping stations, subsequently reducing flow rates which, in turn, promotes further depositions.

FOG build-up and blockages cause millions of pounds of damage to our assets and traditional methods of sewer cleansing to remove obstructions and keep wastewater flowing cost over £10m every year.

Solution

Tackling the problem at source is often the most cost effective solution. We've developed educational programmes to help explain the scale of the problem and provide simple and practical advice to our household customers on how to best dispose of FOG and we also offer customers a free 'gunk pot' - a small container to dispose of FOG. And we engage with non-household customers to establish best practice and practical solutions to help manage their FOG waste appropriately.

While educating our customers is the most sustainable long term strategy, we also need to develop cost effective methods to deal with today's FOG problems.

We're trialling a UK first FOG mitigation product. It's been successfully used to clean up oil spills in the sea, and has shown real potential for FOG mitigation in sewers. The solution works by bio-augmenting the activity of indigenous micro-organisms in the sewer and prevents the formation of hard FOG build-up - keeping wastewater flowing, pumping stations running smoothly – and with lower energy consumption. It can be dosed at suitable points in the network and requires minimum refilling interventions by our operational teams.

Dosing unit being filled by local operators

Implementation

We've worked collaboratively with international partners, Next Filtration (a USA based company), and conducted an extensive trial at 11 of our sites using their 'Next FOG-Stop' product. The trial tested the solution's effectiveness in diverse and challenging parts of our network, including sewer pumping stations, food establishment discharge points, sewage treatment works and combined sewer overflows.

Results have demonstrated the solution significantly reduced FOG build-up in most applications – leading to sewer pumping efficiency improvements and significantly reducing the requirement for manual intervention.

We've developed a rolling plan to review sites with a history of FOG problems and we're analysing each to establish the most cost effective totex solution to deal with FOG build-up.

Breadsall sewage pumping station before and after dosing

Benefits so far

The financial benefits are likely to be substantial - derived mainly from direct opex savings. We also expect capital investments savings due to prolonging the life-span of assets (e.g. pumps) and through enabling proactive maintenance of our network.

This solution can lead to:

- reduced sewer flooding events;
- more cost effective and reliable network maintenance: and
- protection of our local and wider environment.