Appendix 17b: Bioresources technical appendix

YorkshireWater

1. Bioresource Technical Appendix

1.1. Introduction

The appendix has been created as an appendix to the Bio resource business plan narrative document. It provides a greater level of detail around 2 aspects of the plan;

- Treatment Service
- Market Testing Engagement

1.2. Treatment Service

1.2.1. Summary

The Treatment Service is an internal measure we will use with Waste Water Networks Plus (WWN+) to ensure that 100% of sewage sludge is transported, treated and disposed of in the most efficient way possible. The means of treatment could be either internal or external capacity. The Treatment Service will be measured using internal service level agreements between the WWN+ price control and the Bioresource price control.

Our target is to achieve 100% treatment service. This represents a significant improvement from the current period, where we have faced reliability, flooding and safety challenges.

1.2.2. Track Record

AMP6 has seen down time on YW bioresources assets that have reduced treatment capacity. Our resilience plans for AMP7 seek to guarantee that capacity with either YW or third-party assets.

Our AMP7 plans are shaped by the lessons we have learnt from AMP6. Our track record in providing a treatment services to WWN+ has been largely successful – the instances where failure to provide a bioresources service have impacted on the sewage services that the business offers to customers are rare. The challenges that Yorkshire Water have faced in AMP6 are the lack of resilience in our assets and processes and the cost that has been incurred because of this shortfall.

In December 2015 Yorkshire experienced significant rainfall deemed a 1:150 return period in several catchments across the region and the subsequent flooding affected the whole

business significantly. The event reduced the sludge treatment capacity to less than half of the demand of the company's sewage treatment works.

The response to this was immediate in bioresources and significant mitigation activity was implemented to continue to provide this service. Temporary centrifuges were employed to remove sludge from waste water treatment works connected to now out of service sludge treatment centres; additional transport services were employed to move increased sludge around the region; and third-party treatment services were procured with providers in the market to allow sludge to continue to be treated.

The period of downtime from this significant event as well as other unplanned outages in our ageing asset base was significant as can be seen in the graph (see **Figure 1**), where only slowly have we received the deficit in treatment capacity to match production through the AMP7 period.

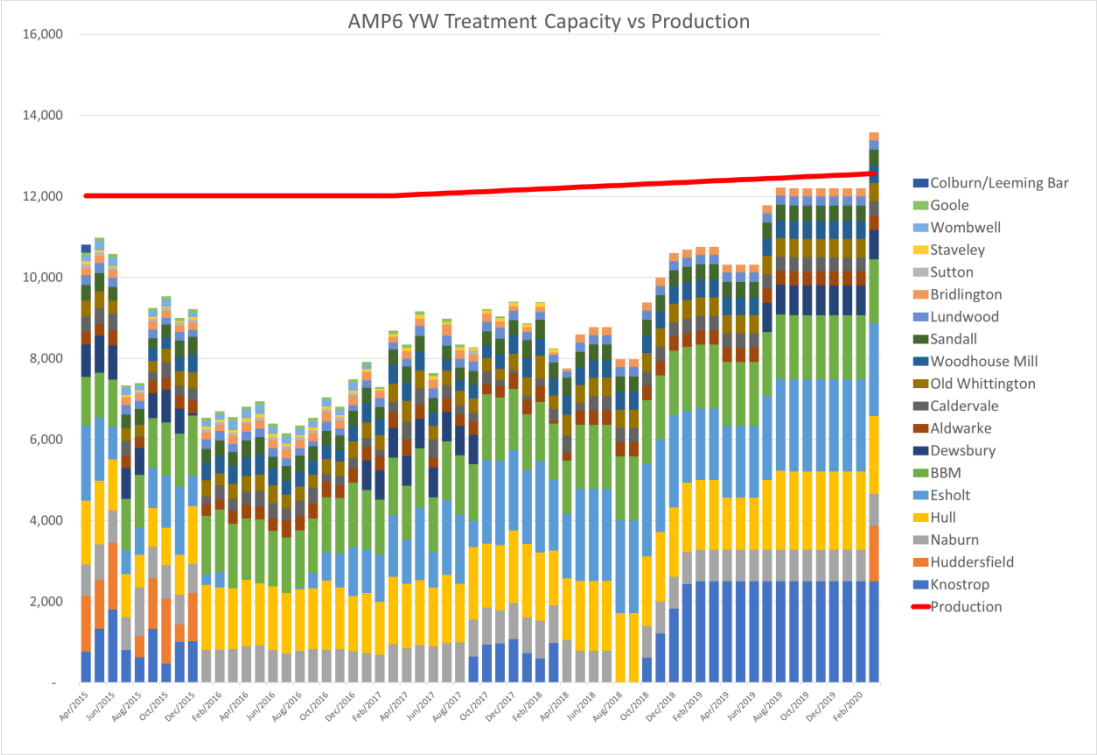

Figure 1: AMP 6 YW Treatment Capacity vs Production

By 2020 we will cease sewage sludge incineration, sludge conditioning and lime stabilisation as primary treatment routes. Our focus will be in on anaerobic digestion, both mesophilic and advanced. These treatment technologies are more efficient and provide additional benefit in a more recyclable product and renewable generation from biogas generation.

The digestion strategy will be complete when Yorkshire Water have finished investment at our Huddersfield and Knostrop (Leeds) sites in 2020 and 2019 respectively.

The transformation of our bioresources activity from just part of the wastewater treatment process to its own functionally separate service comes at a key strategic point for Yorkshire Water as we will have recently completed the delivery of all our digestion capacity. The delivery frameworks that have created this capacity need a new focus as our AMP7 capacity concentrates on asset renewal and refurbishment.

The cost of mitigation and our delivery methods of creating robust capacity show Yorkshire Water as a relatively inefficient bioresources business when compared to other water companies. In 2016/17 Yorkshire Water was the least efficient bioresources company when compared to the 9-other water and sewage companies (WASCs) in England and Wales, shown in the following graph (see **Figure 2**).

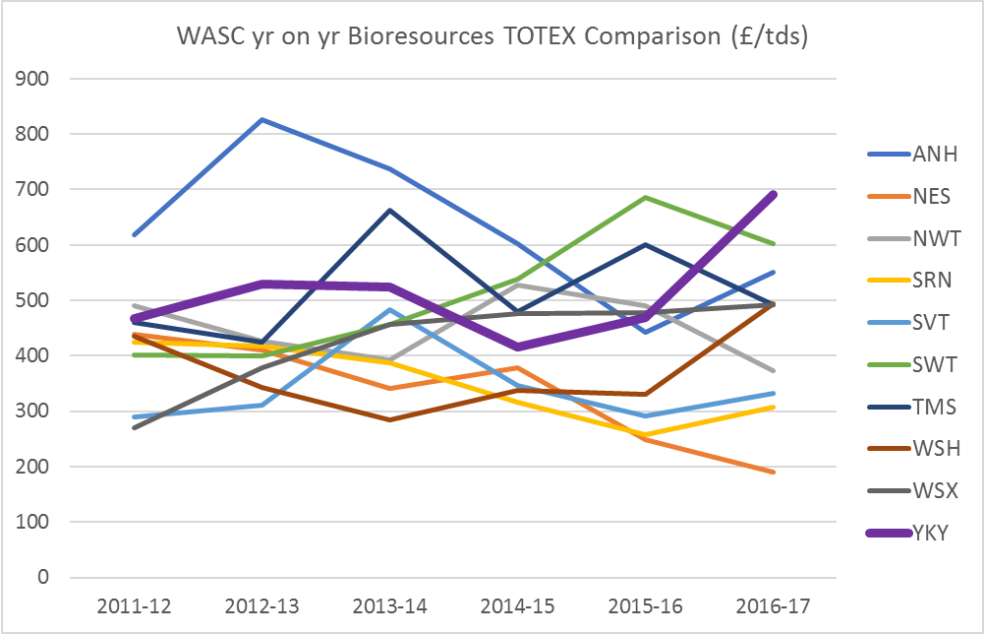

Figure 2: WASC yr on yr Bioresources TOTEX Comparison (£/tds)

1.2.3. Options, Innovation and Resilience

The following diagram (see **Figure 3**) shows our interpretation of the waste water asset base using regulatory guidance and where the Bioresource boundary is including the key asset types within the control. This form the basis of our business planning.

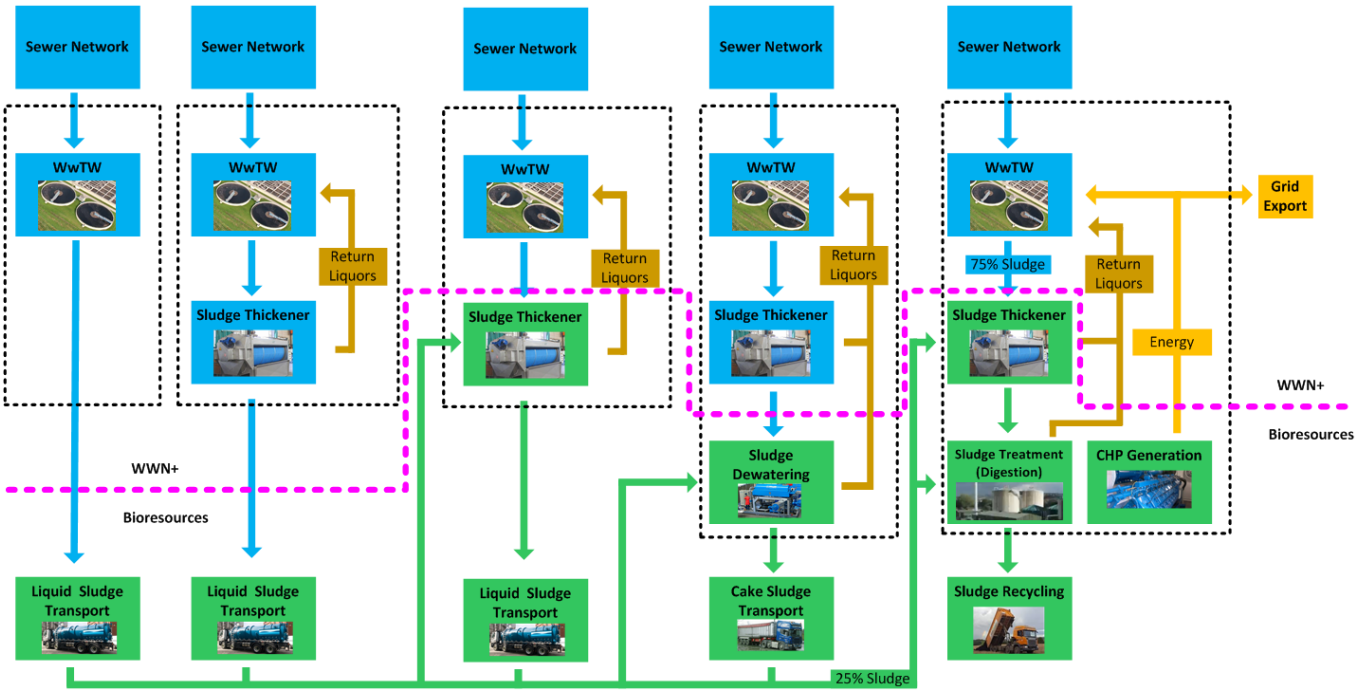

Figure 3: WwTW & STC Network

Our investment and expenditure plan for Bioresources looks at the entire system to ensure that we provide 100% Treatment Service. The plan contains investment in areas not directly related to treatment capacity, but which will enable capacity. For example, through improving the performance and reliability of some of our connecting assets like sludge thickening.

1.2.4. Our Investment Plan

The following table shows (see **Figure 4**) the main components of our plan.

Performance Commitment	Activity	Category	Sub-category
Treatment Service	Transport	Bioresources Transport	Bioresources Transport

<table>
<tr><td rowspan="10">Managing sludge for Yorkshire's waste water treatment works</td><td rowspan="6">Treatment</td><td rowspan="3">Capacity</td><td>New Capacity</td></tr>
<tr><td>Maintaining Capacity</td></tr>
<tr><td>Other</td></tr>
<tr><td rowspan="3">Dewatering & Thickening</td><td>New Capacity</td></tr>
<tr><td>Maintaining Assets</td></tr>
<tr><td>Other</td></tr>
<tr><td>Regulatory Compliance</td><td>Regulatory Compliance</td></tr>
<tr><td rowspan="2">Disposal</td><td rowspan="2">Biosolids recycling</td><td>Recycling Operations</td></tr>
<tr><td>Recycling infrastructure</td></tr>
<tr><td colspan="3">Innovation</td></tr>
<tr><td colspan="3">Resilience</td></tr>
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Figure 4: Yorkshire Water Investment Plan

1.2.5. Bioresources Transport

Our Bioresources transport service is key to providing an excellent service to customers. Collectig sludge in a timely and effective manner from wastewater treatment works ensures environmental compliance, ensures our overall resilience and keeps processes optimised. The flexibility and adaptability of an intelligent, modelled transport service ensures that we

can utilise capacity across our region when we lose capacity to planned and reactive shortfalls.

1.3. Treatment Capacity

Initiative: Tankering outsource – The activity of liquid tankering will be tendered to recognise value savings on the overall delivery cost of a Bioresources service.

Currently cake transport and some aspects of reactive liquid tankering are outsourced activities and we will start a full procurement process for the full transport service.

Assessing the best price from the market for this service ensures our customers do not pay more than they should for this area of the bill. Transport is an area where we think the market has value to offer based on similar activities in other industries. We will be going to market with a logistics contract opportunity for both our cake and liquid requirements.

Our bioresources treatment service is at the core of our bioresources operation. By providing (see **Figure 5**) resilient and efficient capacity we drive the overall performance of bioresources at Yorkshire Water. We will need to create new capacity for Yorkshire Water sewage sludge in AMP7 as a result of growth in production. Our approach ensures that we don't provide too much or too little capacity and always seeks market prices for provision of that capacity to ensure it's efficient. In Bio 1, we articulate that a small proportion will efficiently be treated by a 3rd party, but the table below (figure 5) shows that capacity will be greater than production. It should be noted that we will have headroom for unplanned outage and this is why there is 'spare capacity'.

	2020-21	2021-22	2022-23	2023-24	2024-25	2025-26
Production	152,739	153,648	154,972	160,254	176,449	177,358
Capacity	161,519	161,409	162,772	179,264	179,264	179,264

Figure 5: AMP7 & 2025 Production & Capacity

Our investment plan for the bioresources service is built on creating resilient and efficient capacity (either on YW assets or with third-parties). We have followed a robust process.

Our approach seeks to meet four key tests (see **Figure 6**):

1. Does the programme meet our 2025 capacity requirement?
2. Does the programme ensure no shortfalls in sludge treatment capacity on a monthly basis, over the whole AMP?

3. Is the programme resilient (no sludge shortfalls) to unplanned events with a confidence of at least 95%?
4. Is the programme the most efficient of the scenarios that meet the above three tests?

Figure 6: 4-step test

This process shown below (see **Figure 7**), looks at the sludge production and capacity of the future; identifies a wide range of solutions to meet our four key tests and evaluates them to identify the optimal programme.

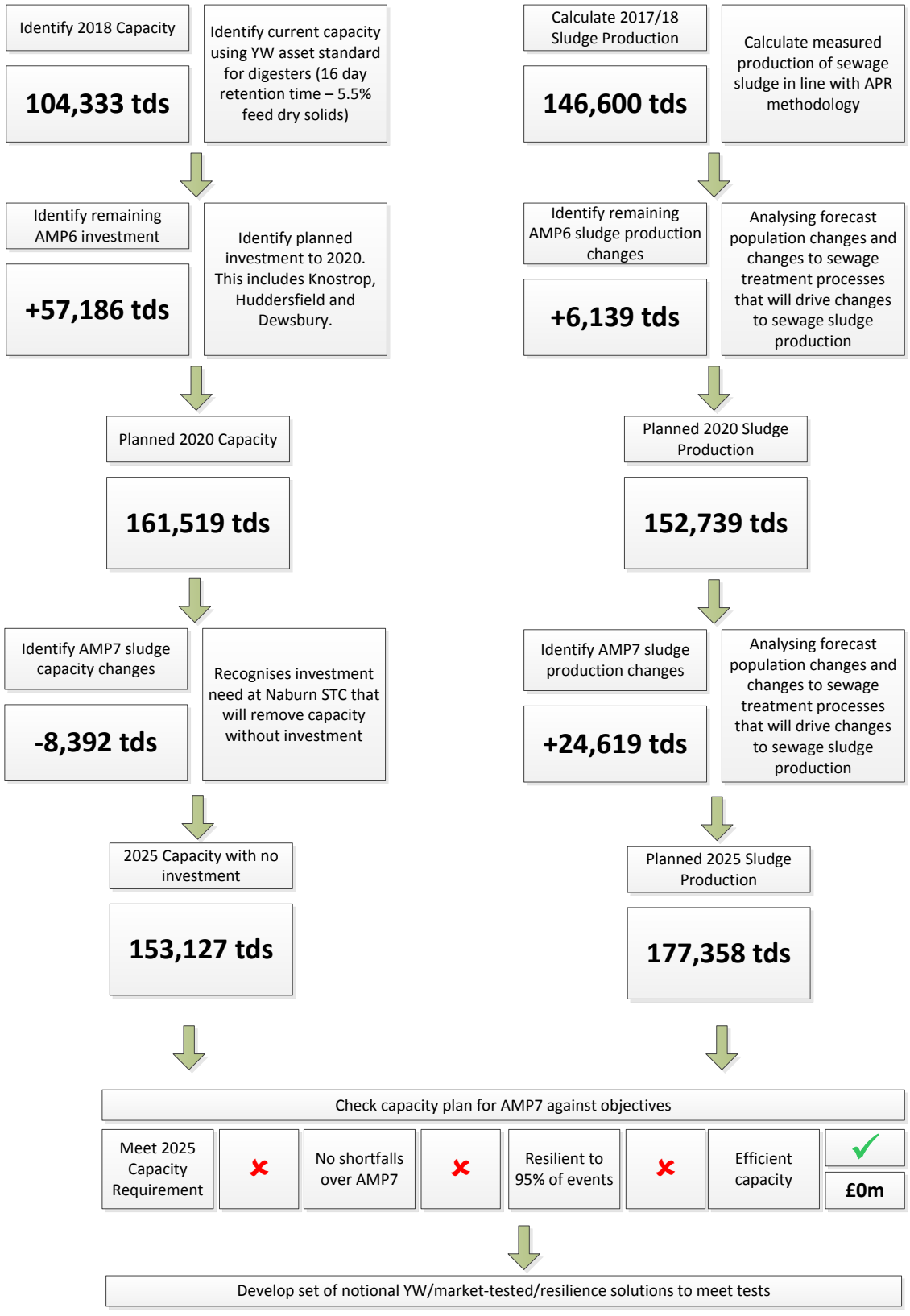

Figure 7: 4-step test

1.3.1. Forecasting Production

Yorkshire Water's waste water treatment works are forecast to produce 152,739 tds in 2020/21 rising to 177,358 tds in 2024/5 as a result of population growth and significant additional treatment requirements driven by the WINEP programme.

The methodology for forecasting this production, produced with our partner ARUP, is outlined in appendix 1 of this document.

Using the sludge production methodology in appendix 1, the graph below (see **Figure 8**) shows how the level of sludge production will continue to increase in AMP7 creating a further deficit in our internal treatment capacity.

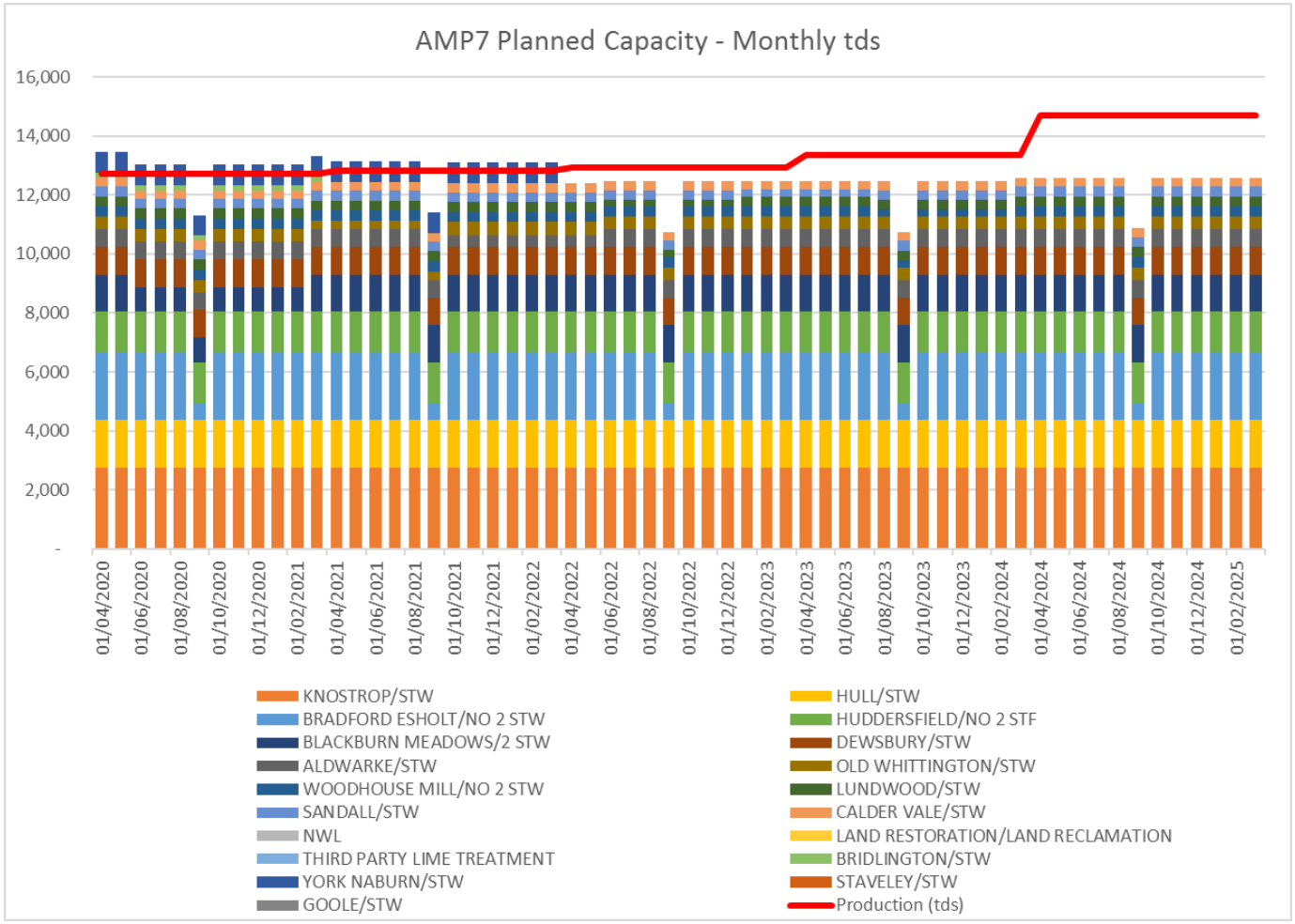

Figure 8: AMP7 Planned Capacity – Monthly tds

The asset base we will have at 2020 is based on our 2018 asset base and forecast investment between 2018 and 2020. We are building large sludge treatment centres at our Leeds site Knostrop and at Huddersfield. We also take into consideration the asset

condition, age and performance of all our facilities. We have a range of asset ages and some of our older assets will need significant refurbishment and renewal in the AMP7 period. One example of this is at Naburn (York). In addition to this we know that some of our assets will need planned shutdowns, during which, our capacity will drop. The outlook for treatment capacity over AMP7, has therefore when taking account, the impacts of Population Growth and WINEP, cumulative shortfall of 46,167 tds across the AMP.

1.4. Investing for New Capacity

We recognise that the historic approach of building new digestion capacity to provide treatment capacity will not always provide the most efficient solution. Because of this, we have considered a number of ways of providing treatment capacity in order to present the most optimal to customers. These options are:

- Build new/additional capacity using existing capital delivery frameworks (mesophilic AD)
- Build new/additional capacity using market tested capital delivery frameworks (mesophilic AD)
- Create capacity at existing conventional digestion sites utilising advanced anaerobic digestion (existing frameworks or market tested frameworks)
- Procure outsourced treatment contract for sludge (outsourced capacity) using market tested frameworks
- Create flexibility in existing capacity with enhanced operations and maintenance approach or with minor capital investment to remove 'bottle-necks'

Each scenario uses combinations of the intiatives that Yorkshire Water have used to create efficient capacity. This is shown in the table below (see **Figure 9**).

Initiative	Approach	Description
Refurbish Naburn UCD Cost	Conventional YW	The unit cost database (UCD) price for refurbishing our Naburn STC which will lose capacity without further investment
Decommission Naburn	Conventional YW	The cost of decommissioning Naburn, should capacity be created elsewhere
Outsource North Area Sites (5,000 tds)	Market-Tested	A market tested price for exporting 5,000 tds of sludge to a neighbouring water company
Outsource North Area Sites (2,000 tds)	Market-Tested	An assumed scaled version of the above market tested initiative
Export Sludge Agreement to WASC	Market-Tested	A market tested solution for exporting 14,000 tds of sludge to a neighbouring water company
Build 5th & 6th Digester at Knostrop STC	Conventional YW	A UCD price for building a fifth digester and sixth digester at our Knostrop STC. AMP6 investment scheme designed to allow efficient expansion.
Build THP at Knostrop STC (Conventional Delivery)	Conventional YW	A UCD price for building an advanced digestion THP at our Knostrop STC. AMP6 investment scheme designed to allow efficient expansion.
Refurbish OOS 5/6th Digesters at Hull STC	Conventional YW	A UCD price for building a fifth and sixth digester at our Knostrop STC. AMP6 investment scheme designed to allow efficient expansion.
DBFO THP build at Hull STC (Basic)	Market-Tested	A market tested option for design-build-operate-finance (DBFO) of THP at Hull STC

DBFO THP build at Hull STC (Extended)	Market-Tested	A market tested option for design-build-operate-finance (DBFO) of THP at Hull STC
Build THP Blackburn Meadows STC (Conventional Delivery)	Conventional YW	A UCD price for installation of THP at Blackburn Meadows STC
DBFO THP build at Blackburn Meadows STC (Basic)	Market-Tested	A market tested option for design-build-operate-finance (DBFO) of THP at Blackburn Meadows STC
DBFO THP build at Blackburn Meadows STC (Extended)	Market-Tested	A market tested option for design-build-operate-finance (DBFO) of THP at Blackburn Meadows STC
Resilience Solutions	Conventional YW	A package of initiatives included in base maintenance programme that deliver resilience in planned capacity (see resilience section)

Figure 9: Scenarios to improve capacity

A scenario analysis of these options (see **Figure 10**) identifies the best scenario for meeting all four key tests for our capacity programme:

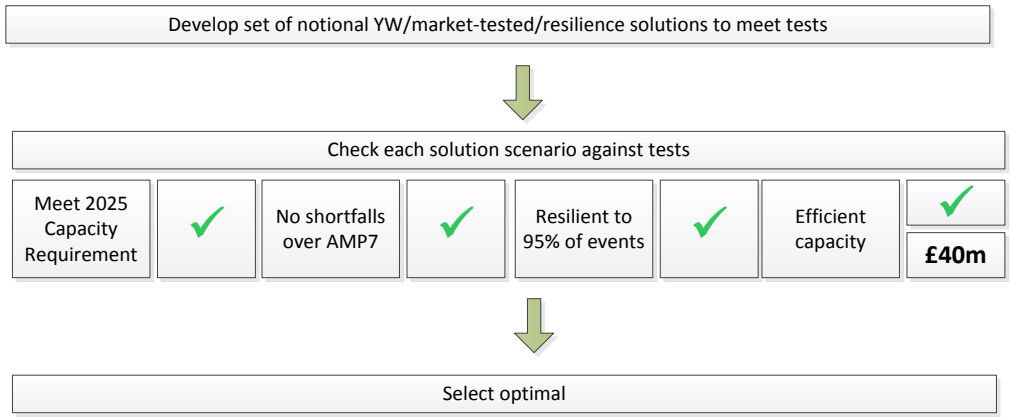

Figure 10: Key tests for Capacity

The preferred scenario comprises the following initiatives (see **Figure 11**):

Initiative	Delivery Route	Site	tds Capacity Created	CAPEX (£m)	Annual OPEX Impact (£m)
Decommission Naburn	Conventional YW	Naburn	-	10.00	- 0.36
Outsource North Area Sites (2,000 tds)	Market-Tested	North Area	2,000	-	0.65
Build 5th & 6th Digester at Knostrop STC	Conventional YW (fully tendered)	Knostrop	16,492	24.61	1.43
Refurbish OOS 5/6th Digesters at Hull STC	Conventional YW	Hull	9,755	11.00	0.43
Resilience Solutions	Conventional YW			-	-

Figure 11: Preferred Scenario

The table shows that there is a proposal for a mixture of conventional and non conventional options to deliver our most efficient treatment capacity objectives to meet the shortfall identified in our modelling. The market tested inititaive is based on discussions we have had with supplier companies and neighbouring water companies. This is discussed in more detail below.

This programme has been assessed as deliverable based on internal/external scrutiny of the market tested and YW based prices although contracts have not been signed.

Further procurement exercises have now started to implement the programme of work to provide bioresources capacity in Yorkshire Water.

1.5. Innovation

Our innovation approach is designed to ensure our assets deliver efficiency and resilience both now and into the future. We believe innovation has a key role to play in exploring opportunities and risks that do not currently present themselves but could do before 2045. By exploring these now in a planned and managed way we can prepare for potential shocks. Innovation in Bioresources falls into three areas in line with a company-wide innovation strategy.

- Research and Development Innovation – The aim of Research and Development (R&D) innovation is to fill gaps in knowledge, services and products which cannot be provided by the supply chain or by process changes, with the Business taking ownership of delivery. The programme establishes a small number of significant, high value projects informing transformational change.
- Cultural Innovation – Cultural Innovation is how creative, collaborative and process driven colleagues within the business are to make positive changes in how the company delivers services. It is the day to day process of continuous improvement. It also demonstrates the maturity and capability of partners, and their aspiration, to suggest or make those changes.
- Supply Chain Innovation – Once articulated, if a risk or opportunity cannot be mitigated or realised through process change by colleagues or partners, the Supply Chain should be stimulated utilising the Procurement process. This in turn is dependent upon the ability of the business (client and Procurement colleagues) to articulate and specify on which the supply chain can deliver. The procurement process should be 2-way to allow innovative solutions to be offered over traditional solutions. Innovation funding is not primarily designed to trial at-market solutions unless as a last resort if they cannot be evaluated by conventional means.

1.6. Example of Innovative Approaches at Yorkshire Water in Bioresources

The Circular Economy at Esholt

Transformational Research and Development Innovation has been revolutionised by creating options for future operating models. An example of this is the Integrated Water, Waste and Resource System concept. This has been tested with the YorWater Online Community with an 87% positive response and comments. The concept is being demonstrated at Esholt Waste Water Treatment Works, Bradford. The vision sets the agenda for research (commercial, academic and at market technologies) into bringing redundant operational land back into production. This land will be made available to attract domestic and industrial customers to locate in proximity to our operations to access sustainable resilient wholesale products such as water (potable and subpotable) and heat. Following initial work to realise the value of the redundant operational footprint at Esholt (see section Innovation Track Record), the concept of circular economy demonstration has been articulated which draws in our customers to utilise resources we can recover from our immediate environment. The attention this thought leadership is attracting suggests this systemic approach is both stretching and unique in its ambition. For example, heat, power, water (both potable and subpotable), nutrients, cellulose and raw materials for the chemical industry can all be derived. Attracting business which can utilise these resources allows YW to deliver existing wholesale products more sustainably whilst providing new wholesale products, thereby realising customer value. A housing development is currently in planning. This will be an exemplar development, designed with water sensitivity at its heart, driving down domestic consumption, water re-use, sustainable urban drainage, cutting edge metering technologies as well as a heating circuit. Localised industry will take advantage of the same resources.

In addition, controlled environment agriculture, or vertical farms, will deliver year-round high value crops without the need for pesticides. There is a clear alignment with the co-location of data centres in proximity to waste water treatment works providing power and cooling. Redundant lagoons will provide a form of flood attenuation and raw water resources. The model is in development and will demonstrate the value proposition, through the 6 Capitals approach, informing the conditions for roll out in whole or part at other YW sites. Stakeholder partners are engaged. Bradford Council and the Local Enterprise Partnership, Leeds City Region are supporting the articulation and development of the programme. The concept has been described as having European significance.

SAP Plan to Manufacture

We're implementing an innovative approach to the management of our Bioreosurces production line. By thinking of our sludge treatment centres more like lean manufacturing centres than waste treatment sites we believe we can deliver incremental efficiencies on our operational costs.

Lean manufacturing organisations utilise SAP tools to do this and we're implementing the Plan to Manufacture workstream to realise the benefits they see

Its key characteristics are:

- Optimise production across all our sites
- Use real time cost information for each site
- Identify customer demand hotspots
- Manage & report on asset outages
- Monitor flows & demands
- Easily produce reports, plans & reforecasts

The benefits for bioresources are:

- More cost effective
- Optimises capacity
- Real-time decisions
- More effective planning, forecasting & reporting
- Fully integrated

1.6.1. Gasification of Sewage Sludge

YW produces 150,000 tonnes dry solids of bioresources a year. By the end of AMP 6, all this will be treated by anaerobic digestion with the remaining material used as fertiliser in agriculture. This is an industry standard methodology, safe and reliable. YW uses 600GWhrs of electricity a year with an associated cost of over £50m. AD could get us to 26% self-sufficiency. For ten years YW has researched and developed alternative ways of liberating more energy from its bioresources. This has culminated in the industrial scale demonstration of a gasification technology as a pre-commercial technology.

The delivery of commercial and technical models and an asset standard, over 10,000 hours of operation has demonstrated a carbo negative, commercially advantageous asset that

could deliver energy self-sufficiency. The project was significantly supported by DECC (Energy Entrepreneur's Fund). YW is currently seeking innovative commercialisation routes where customer and environmental benefit can be secured for the long term. Our commercial research suggests that this is a global first, the highly efficient gasification of sewage sludge, demonstrated at commercial scale.

1.7. Resilience

1.7.1. Gasification of Sewage Sludge

Resilient, reliable and sustainable water and wastewater services are essential for people, for the economy, and for the environment. Providing resilient bioresources capacity feeds into the resilience of our wastewater services and how we protect the environment.

Our planned capacity (provided through in-house and market routes) can treat all the sludge that we forecast to produce in AMP7. A resilient plan, however, needs to go beyond the planned events and manage the uncertainty of the future.

Our plan for resilient capacity in bioresources works within the wider resilience framework for Yorkshire Water, details of which can be found elsewhere in the FBP. We also think that the standard industry broad-brush approach of building a set 'head-room' in facilities is not nuanced enough to demonstrate a resilient capacity. Resilient capacity needs to be able to deal with the 'stresses and shocks' of the future.

The Yorkshire Water approach to providing resilience capacity takes advantage of an innovative 'bioresources resilience model' to understand and appraise uncertainty in bioresources treatment. The most cost-effective solutions to provide resilient capacity can be modelled, analysed and optimised.

1.7.2. Modelling Uncertainty

The experience of AMP6 has shown us that a combination of events can severely impct treatment capacity and efficiency. Yorkshire Water's bioresources capacity has been impacted with reliability, flooding and safety issues.

The future is increasingly changing and unpredictable. Acute shocks such as extreme weather events and chronic stresses such as aging assets need to be modelled.

A combination of historic analysis and future forecasting informs the events that our bioresources strategy will need to weather, an example of which is shown below (see **Figure 12**).

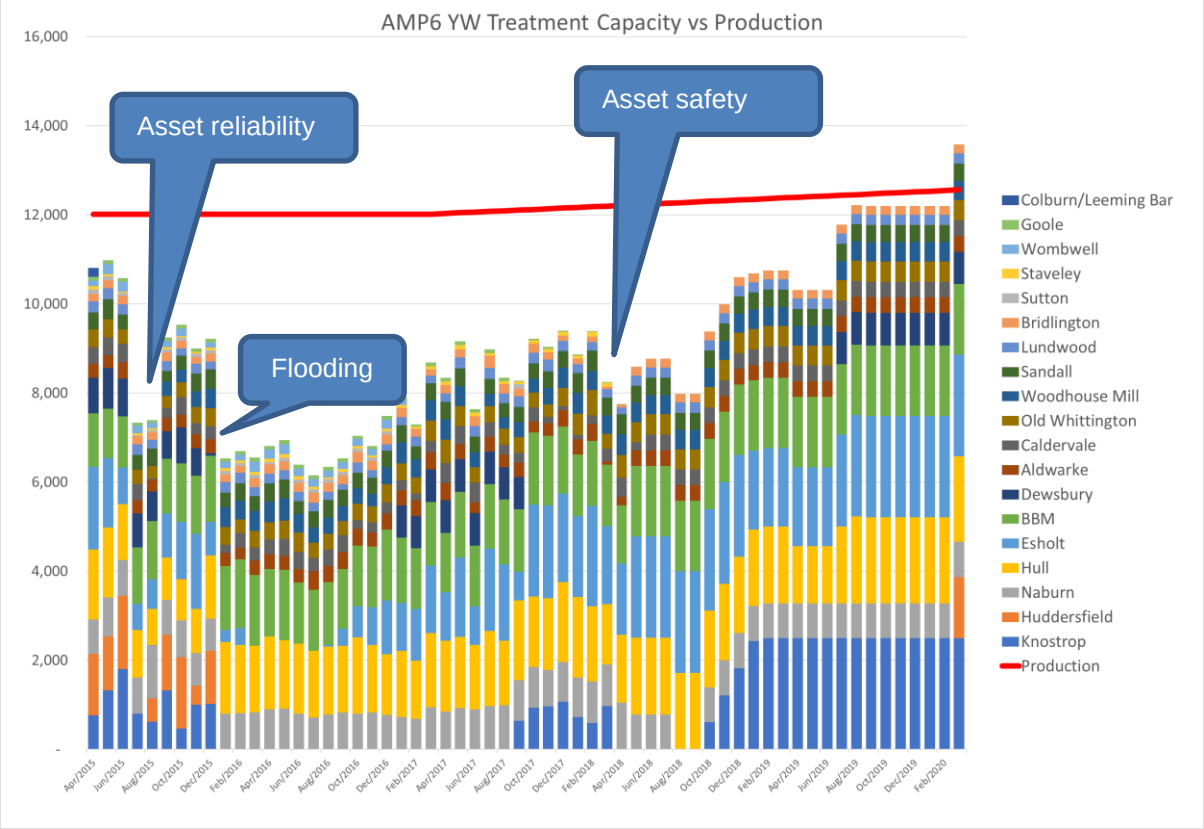

Figure 12: AMP6 YW Treatment Capacity vs Production

We have built a resilience model to examine and analyse the impact of potential events on YW's overall ability to provide a treatment service. This resilient model examines potential impact events (such as acute events and chronic stresses) and allows Yorkshire Water to consider the variable impact of mitigation against these events.

Our resilience model brings together capacity and potential events to analyse solutions against our resilience target (95% of all events managed with no surplus sludge):

1. Capacity – Market solutions for emergency/planned capacity, flexibility in capacity (e.g. optimising digester retention times) and baseline capacity
2. Impact events – External risks (e.g. flooding, farming impacts), known asset risks (e.g. digester failure) and historic events (e.g. centrifuge downtime
3. Modelling – Monte Carlo analysis of 1,000 iterations to create a probability distribution of sludge treatment surplus and deficit

Solutions – Investment/operational interventions to either increase capacity or reduce likelihood of impact events.

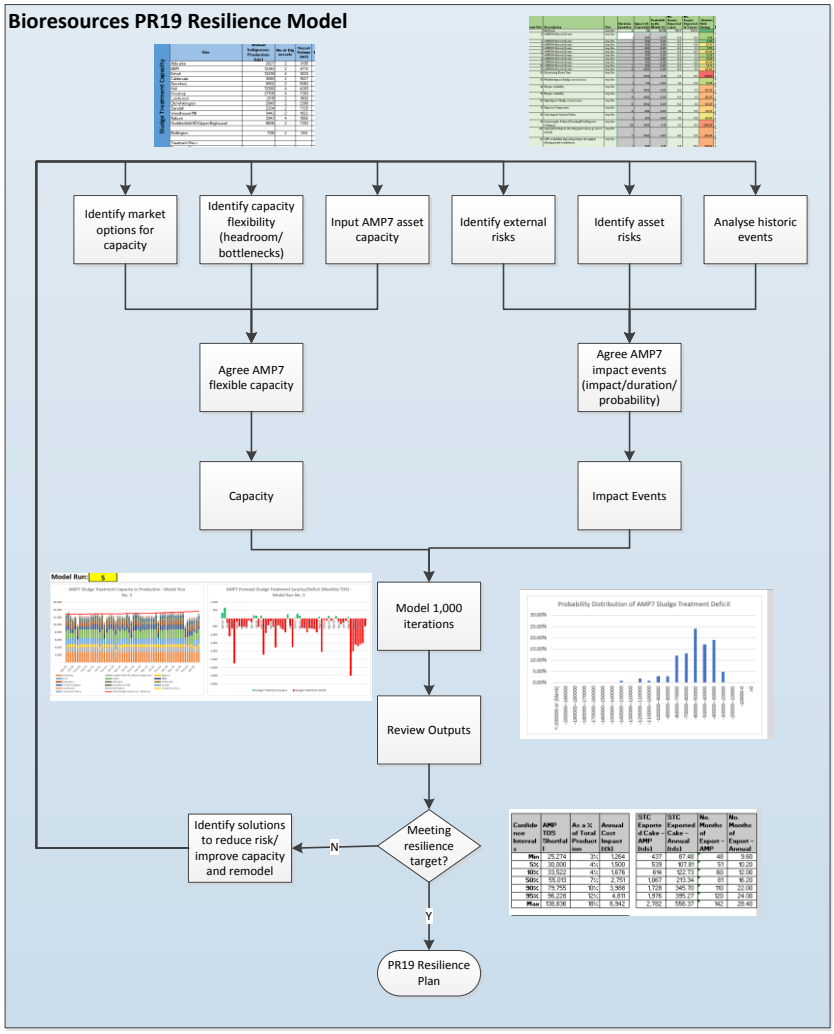

Figure 13: Bioresources PR19 Resilience Model

The graphic above (see **Figure 13**) shows a snapshot of our resilience model.

Our resilience approach uses solutions in five areas:

1. Resistance (protection to withstand a hazard)
    a. We have considered flood protection and cold weather protection where appropriate
2. Reliability (ability to operate in a range of conditions)
    a. We have considered an enhanced maintenance approach and the reduction in impact events this might deliver
3. Redundancy (designed capacity into a system)
    a. We have considered additional capacity provision and the cost of that provision

    b. We have considered the ability of our assets to manage greater throughput by altering certain operational parameters
4. Response and recovery (enabling fast and effective response to an event)
    a. We have considered the facilities that allow us to remove sludge quickly from systems and import it back easily into the treatment network
5. Reflection (learning from experience)
    a. We have built a resilience model that captures the learning from past events
    b. We will iterate and evolve our resilience model as our understanding of past and future events develops (a live tool for planning and optimisation)

The result of our resilience analysis is a prioritised list of risk-based investment, part of our base programme, that allows us to guarantee our capacity in line with our strategic objective (we will guarantee treatment capacity with a 95% confidence level.

Our proposed resilience plan is supported by the following investment initiatives:

1. Outsourced north area treatment – providing guaranteed capacity for 2,000 tds of sludge
2. Investment in Blackburn Meadows liquor treatment to remove a bottle-neck on digester retention time flexibility
3. Enhanced maintenance approach to Esholt shut down – reducing the down time of the THP from 3 weeks to 1 week
4. Digester Refurbishment Programme – improving reliability of heating and pumping systems
5. Enhanced Maintenance Approach – reducing the likelihood of failure and improving response times to issues
6. Plug and play centrifuge approach – allowing YW to respond quickly to failure on dewatering assets
7. Outsourced dewatering and thickening – improving reliability and throughput for key assets

2. Market Testing Engagement

In the main narrative section, we touch on the various initiatives we have implemented to ensure that our plan is lean and efficient. Market testing is a significant part of our strategy to move from lower quartile in the industry to an improved position on efficiency. In our market testing, we have the following objectives;

- Pursue increased trading
- Utilise third parties
- Stimulate and develop the market
- Collaborate to do more

2.1. Pursue increased trading

We are working to pursue and promote sludge trading in order to increase the efficiency of providing bioresources services and resilience, in line with our treatment service performance commitment. Yorkshire Water share the view that sludge trading provides significant opportunities, both this AMP and beyond. We see these opportunities in two key areas:

- Flexible, no-volume agreements which can be called on reactively
- Fixed, longer term agreements with guaranteed capacity

These arrangements support increased resilience of both Yorkshire Water and the Bioresources industry by providing a wider range of pre-agreed treatment options to call upon, either on a regular basis or in response to incidents and outages.

We have already carried out in-depth modelling to understand where to target these savings through trading, considering the efficiency of treating sludge at each of our works and transport costs to the relevant Sludge Treatment Facility (STF). This allowed us to identify those sites around the edges of our boundary where exporting our sludge, or importing other companies' sludge, will be economically beneficial (see **Figure 14**).

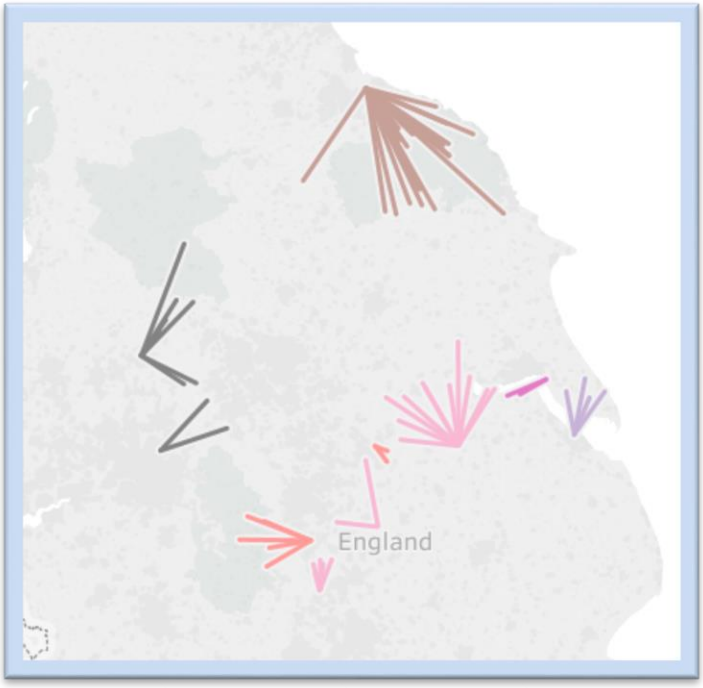

Figure 14: Modelled trading across water company boundaries

We explain in the main narrative document how Yorkshire Water has already been working to develop reactive agreements with nseveral WaSCs on this basis, and how we have been looking at the potential for including fixed, longer term agreements as part of our PR19 plans as an alternative to building new capacity.

2.1.1. Flexible, reactive agreements

This AMP we have set up several short-term trade agreements with Severn Trent, Northumbrian Water, Anglian Water and United Utilities, who as neighbouring WaSCs provide a more efficient source of regular treatment capacity for some of our periphery sites and a viable trade opportunity to replace any short-term shortages in capacity. Sludge quantities to trade are agreed on a weekly basis, depending on available capacity at the relevant site and demand.

In addition to benefitting the environment and ultimately lowering customers' bills, these pilot agreements will give us the opportunity to understand how best to structure operational and contractual arrangements to maximise the future trading market.

We believe there is significant opportunity for these flexible agreements to be utilised more. Our experience of sludge trading suggests that a more effective market could be realised through being more liquid, with more dynamic and easy-to-use information easily available to all. This would allow trading to become a more reactive service, open to a wider range of market participants and able to respond to short term changes in capacity, in addition to facilitating long term arrangements.
We believe this can be achieved through a Nationwide Sludge Trading Hub.

2.1.2. Fixed, long term agreements

We believe long term and fixed trade agreements can deliver efficiencies either by treating ldge at more conveniently located or more efficient sites, or by making use of existing capacity as an alternative to building new works.

Our analysis of sludge treatment efficiency identified several sites in the North of our region where we believecost savings and environmental benefits can be delivered through a long-term trading arrangement to a more conveniently located treatment site (brown lines going from many STWs into one Northumbrian Water STF in **Figure 14** above).

Whilst we are trialling short term trading arrangements with Northumbrian Water (see **Flexible, reactive agreements**), we wanted to engage with a wider audience of potential suppliers regarding any AMP7 longer term contract. As part of the market testing exercise described under **Utilise third parties**, we asked the market how it could best provide innovative and cost-effective solutions for the collection, treatment and recycling of sewage sludge from up to 192 of our treatment facilities spread across North Yorkshire and the Yorkshire East coast.

We also considered, and are continuing to progress, whether trading could be a viable alternative to refurbishing one of our large 14,000 tds Sludge Treatment Facilities in York.

We have had significant engagement with and interest from the market in trading as a long-term solution. Please see **Market testing the provision of services** for more information.

2.2. Utilise third parties

A substantial element of our approach to achieving our targeted efficiency is to work with a wider range of companies that can help us think differently about how we provide bioresources services. We recognise we can't be experts in everything and have been listening to companies that do hold the expertise in order to design an outcome based PR19 programme. In doing this we're looking to collaboratively and innovatively deliver efficiency and improve performance beyond our current approaches; through new technology, greater specialism and understanding or commercial innovation.

In advance of our PR19 submission we have been carrying out a series of engagement activities, aimed at stimulating interest in the market and gaining an understanding of how we can structure our PR19 plan to maximise opportunities for efficiency.

The first phase of this work included going to the market to engage on nine packages of work which collectively made up over 80% of our bioresources capital programme.

The results of this work have significantly altered how we plan to deliver bioresources services next AMP and have identified potential savings of around £100 million which have been incorporated into our plan.

Further information on our market engagement approach can be found under **Collaborate to do more.**

2.2.1. Market testing the provision of services

In January 2018 we went out to the market to engage on nine packages of work, selected based on where the greatest savings were envisaged and the shortest timescales for realising the benefits. These packages made up over 80% of our bioresources capital programme and were offered on an outcome basis, providing the market freedom over how it approached the requirement.

Capital Delivery Efficiency

1. Delivery of our Digester refurbishment programme,
2. Delivery of our Thickener refurbishment programme, and
3. Delivery of our Dewatering refurbishment programme.

Naburn Sludge Treatment works

4. Complete refurbishment of the existing sludge treatment facility at Naburn STF in York
5. Complete refurbishment of the existing sludge treatment facility and extension of the existing Sewage Treatment Works (STW) at Naburn in York.

'Off-take' solutions

6. Provision of an emergency liquid sludge treatment service; this could include providing facilities to turn this into cake sludge and transporting to a local facility for treatment,

7. Collection, treatment and recycling of sewage sludge from up to 192 treatment facilities spread across North Yorkshire and the Yorkshire East coast, and
8. Management of excess biogas which is not currently being utilised.

Enhanced treatment provision

9. Provision of solutions to enhance the efficiency of existing mesophilic Anaerobic Digestion works.

We reached out to over 90 companies which were a mix of large Tier 1 suppliers and bespoke, more specialised organisations, and received initial feedback from more than 30. During this first phase we were most interested in understanding:

- Whether the market was interested in the package,
- What solutions they proposed, and
- What terms Yorkshire Water needed to offer for the market to deliver it most efficiently.

Following review of the initial findings these packages were re-developed in line with market comments, which included combining some lots, removing others and notably including operation and maintenance with the refurbishment of assets. There was a notable lack of appetite for provision of an emergency sludge contract; companies did not see this as an attractive offering and did not want formal agreements for this service. However, we feel some resilience against emergency events can be provided through the flexible, reactive agreements described under

Flexible, reactive agreements.

The updated packages, (see **Figure 15)**, were developed into a pricing specification and shared with market participants with a request for budget estimate proposals.

Figure 15: Final market-tested packages

Those companies that responded to this pricing specification provided a range of potential solutions, some of which looked makedly more efficient than our originally costed solution.

Following the results of this research the solutions built into our Bioresources core programme are notably different and have significantly altered how we plan to deliver bioresources services next AMP.

Rather than our traditional in-house delivery, we will be taking to the market complete outsourcing of thickening and dewatering at all transfer sites across our region. We will be relaxing our asset standards and procuring on an outcome basis, to give the market freedom of how it delivers this capability over a fifteen-year contract.

We are looking to procure additional sludge treatment capacity, to help us manage an increasing population and additional sludge forecast as a result of the National Environment Programme (WINEP). Our own capacity scenario modelling has given us a clear view of how to create this capacity within our own sites most cost effectively, and we plan to share the costs of delivering this approach on a £/tDs basis with the market and asking them to beat it.

Through this approach we will be offering outsourced delivery of at least 15,000tDs sludge treatment capacity to the market and are remaining technology agnostic, so long as the proposed solution meets our quality parameters (such as Biosolids Assurance Scheme compliant and contributing to energy generation). The winning approach can therefore be based on the most economically beneficial offer.
Initially, feedback on the market's approach to managing biogas was quite high level and we have since continued engagement with prospective suppliers, including by highlighting the challenge and our aspirations in this area at a Biogas Opportunities Stall at our Bioresources Supplier Day in April 2018 (see **Collaborate to do more**). We now believe there are considerable opportunities available around biogas management including through technologies that are new to us, such as gas-to-grid and gas-to-fuel solutions. Working with specialised market providers offers us the chance for both creating greater value from our biogas, supporting our energy generation performance commitment, and contributing to required emissions abatements. We plan to start by offering to the market outsourced biogas management at three identified priority sites.

Over the coming months we will continue to develop our plans in this area, including defining in more detail, through further market engagement, the lots to be offered (see **Collaborate to do more**). We will also work to further explore the pros and cons of alternative funding arrangements, which the market expressed an interest in, and to develop more specialised internal capabilities to enable market delivery, such as contract management.

This engagement process has highlighted some real opportunities to drive efficiencies into our bioresources business and has identified potential savings of around £100 million compared to our originally costed solutions, which have been incorporated into our business plan.

2.3. Stimulate and develop the market

Whilst working to pursue a range of immediate opportunities around markets, we've also given thought to our role in developing the market and its ability to respond to future challenges. We want to continue to develop bioresources treatment to be increasingly efficient; making the most of new and innovative solutions that can deliver benefits to the economy, society and the environment.

We plan to enable this change by providing support and incentives for the market to develop in areas that align with our long-term bioresources strategy, and by becoming more agile in order to react to evolving technologies and approaches.

Examples of this include:

- Sponsoring research into the optimisation of Anaerobic Digestion, to try and increase gas yields beyond what is currently feasible and enhance pathogen reduction,
- Funding research to enable development of a market in nutrient recovery
- Using data more effectively to incentivise behaviours, for instance factoring in more granular cost parameters into outcome-based contracts so that suppliers can make informed decisions into how to manage services.

We're also looking into how we can build our assets differently so that third parties can easily demonstrate new technologies without disruption to our operations or additional costly investment. This will likely include use of hook up points on some of our assets, so that mobile units can easily be incorporated making us more resilient to failures and able to work with differing technologies, and Innovation Pads, which will give third party providers a site to develop and test their technology in a real-world scenario.

2.4. Collaborate to do more

In our efforts to drive efficiency, boost resilience and deliver further innovation within bioresources treatment, we're also considering how we can involve others more to make the most from opportunities in bioresources.

Incentivising the Nutrient Recovery Market

One area we're particularly interested in incentivising is that of nutrient recovery. Whilst not economically beneficial in the short term we believe this is the right thing to explore in line with our aspiration to protect the environment, and our bioresources objective to get the most from our resources.

We are working with two emerging technologies which recover nutrients for agricultural or industrial use, in addition to other resources such as acetic acid. This can be used as an industrial chemical feedstock and potentially as a cleaning product, which we are currently trialling.

In advance of our PR19 bioresources submission we have been carrying out a series of engagement activities with the market, to simulate interest in working with Yorkshire Water and to understand how we can most effectively package our services to make the most from opportunities in bioresources.

The first phase of this work included market testing over 80% of our bioresources capital programme, by taking nine outcome-based packages to the market and collaborating to develop a more efficient PR19 plan of activities (see **Market testing the provision of services**).

Following this we hosted our first Bioresources Supplier Day, which provided an opportunity for us to engage with potential suppliers on our aspirations for the bioresources business and how we are looking to the market to support us in delivering our company outcomes. A

series of presentations and face to face meetings on the day allowed us to stimulate further interest from the market and get it thinking about how we can work together differently to deliver bioresources services. We had over 100 attendees from 60 different companies attending, ranging from large Tier 1 suppliers to small technology organisations and even other water companies, to ensure we maximise the opportunity for innovation.

In June we held a follow-on session, our Bioresources Collaboration Day, as requested by attendees of the first event. This session presented in far greater detail the lots being offered to the market and the process for bidding and provided a chance to connect a range of companies to facilitate collaboration and ultimately enable more innovative bids.

Most importantly it provided a final opportunity for the market to advise us on how best to structure the services offered in our upcoming outcome-based procurement, including inputting into how the lots were split, the market view on reasonable handover requirements and what outperformance might look like.

Through collaborating with the market throughout the development of our PR19 plans to influence the outcomes we're looking to achieve and the way in which we procure them, we believe Yorkshire Water will be able to deliver a truly transformation bioresources service which delivers benefits for customers, the environment and the suppliers involved in working with us.

Creation of the first "National Test Centre Pads"

Our Innovation team are working to develop Innovation Pads as part of their plans to create value from redundant pieces of land across our Esholt estate, enabling the creation of the first "national test centre pads". By partnering with a commercial entity we wish to provide access to water and waste water products, throughout the treatment process, for third parties to develop their technologies from concept through to a commercially viable product in a real world environment.

Work has commenced to construct up to ten concrete pads (manufactured using final effluent) for the demonstration of technologies. The pads will be managed by a partner organisation on a commercial basis and be open to Capital Delivery Partners, the owners of tech, sponsoring water companies and Universities. The aim is to unblock the supply chain by delivering confidence in technologies demonstrated in a commercial environment.

An additional benefit will be the exposure to the new and emerging technologies for Yorkshire Water, who will in turn be able to have high confidence in the products as they have been tested in our environment enabling quick adoption and realisation of benefits.

Planned projects within bioresources continue this collaborative theme. Our push to develop a Nationwide Trading Hub to enablean agile and reactive sludge trading market is being developed in collaboration with Open Data Leeds, the Yorkshire community of digital developers (see **Flexible, reactive agreements**). Working alongside a partner third party organisation and with funding from DECC, Yorkshire Water has successfully demonstrated a commercial and technical model for the destruction of sewage sludge using gasification. We are currently exploring innovative ways to commercialise the technology, which does not include the customer paying for the capital infrastructure but benefitting from the lower cost to treat. And our development of the first national test centre pads will allow us to support third party providers in developing technologies in a real-world environment.

Appendix 1 – ARUP Sludge production methodology

Yorkshire Water needs to understand the impact of future population change and environmental drivers on sludge production volumes and quality so that it can plan for it.

Arup has been tasked with developing a methodology to estimate future sludge production figures.

The methodology used in building the regional production model is as follows:

1. The list of all existing WwTWs and the respective treatment processes have been obtained from YWS's AI system.

   The largest sites, which treat the bulk of the sewage and are thus responsible for the largest amount of sludge produced have been verified by Arup to ensure the correct treatment processes have been allocated in the model.

2. The residential population estimates for future population were obtained from the YWS Planning department to understand the growth element of the estimates.

   The current population equivalent figures were obtained from AI and used as a basis for quantifying the trade population equivalent by subtracting the residential population

   Combined current and future population equivalent estimates were derived using the two data sets and entered in the model. The trade population equivalent was assumed constant from year to year.

3. The environmental programme for AMP5 as is being delivered at present, and the best estimate of the AMP6 programme were obtained from the YWS Environmental Regulation team.

   The programme was entered into the model by changing, where deemed appropriate, the treatment process to be able to meet the quality driver, e.g. a phosphorous driver on a small site would see a change in process from

trickling filter to trickling filter with chemical dosing, and thus a change in sludge produced.

4. A sludge yield factor table was used to estimate the sludge yield per population equivalent for each process. In addition, the sludge yield was broken down into its components to ensure that the amounts of primary, secondary and chemical sludge could be estimated and better contribute to understand the impacts on sludge treatment assets.

   The sludge yield factors were determined using industry reference values and process calculations.

5. Where applicable, for a limited number of sites, water works sludge being disposed to sewer were also included. The amount of water works sludge was determined as part of the research project on coagulant recovery and were estimated in line with the WRc methodology[1].

   The amount of water works sludge produced has been assumed to remain constant each year and is treated as a chemical sludge due to the high percentage of coagulants.

6. The product of the population equivalent for one site and the relevant sludge yield for the process installed gives the estimated sludge production for the site. These are then summed together for all sites to give a regional sludge production figure.

   The exercise is repeated for each year that is considered, generally the beginning/end of each AMP, and the year of calibration 2016,

   In addition, the model distinguishes between growth and quality drivers, to enable cost separation.

   Furthermore, the STF where the sludge is treated can be allocated to estimate where this is produced and its impact on downstream assets. This has been done by reviewing the logistics business plan figures for tanker and cake movements, where available, or the closest STF to the site in consideration.

7. The model is calibrated against actual data. The reference year was taken as that for the financial year 2016/2017 as reported as part of the CCC17 submission, which is similar in period to the 2016 population estimate year.

   A calibration factor that adjusts all sludge yield factors by the same amount was used to allow both the reported and the one estimated by the model to be similar. The calibration factor was estimated to be 0.89, or in other words the model's output was reduced by 11% and is applied to all estimates of current and future sludge production.

   The main reasons for the need to calibrate the model are:

   - The sludge yield factors will depend on the fraction and type of trade effluent, i.e. some traders have very high strength and thus high

[1] WRc (1992) Water Treatment Processes and Practices, eds Hall, T. and Hyde, R. A., Swindon, UK.

population equivalent effluent with a relatively low solids load which skews sludge production figures;

- Cold digestion is likely to occur in the sewers reducing the load to the works;
- The accuracy of the reported has is likely to range between 5% and 10%.