PR24

NORTHUMBRIAN WATER living water | ESSEX&SUFFOLK WATER living water

A3-18 CLIMATE CHANGE RESILIENCE- FLOODING AND POWER

NES32

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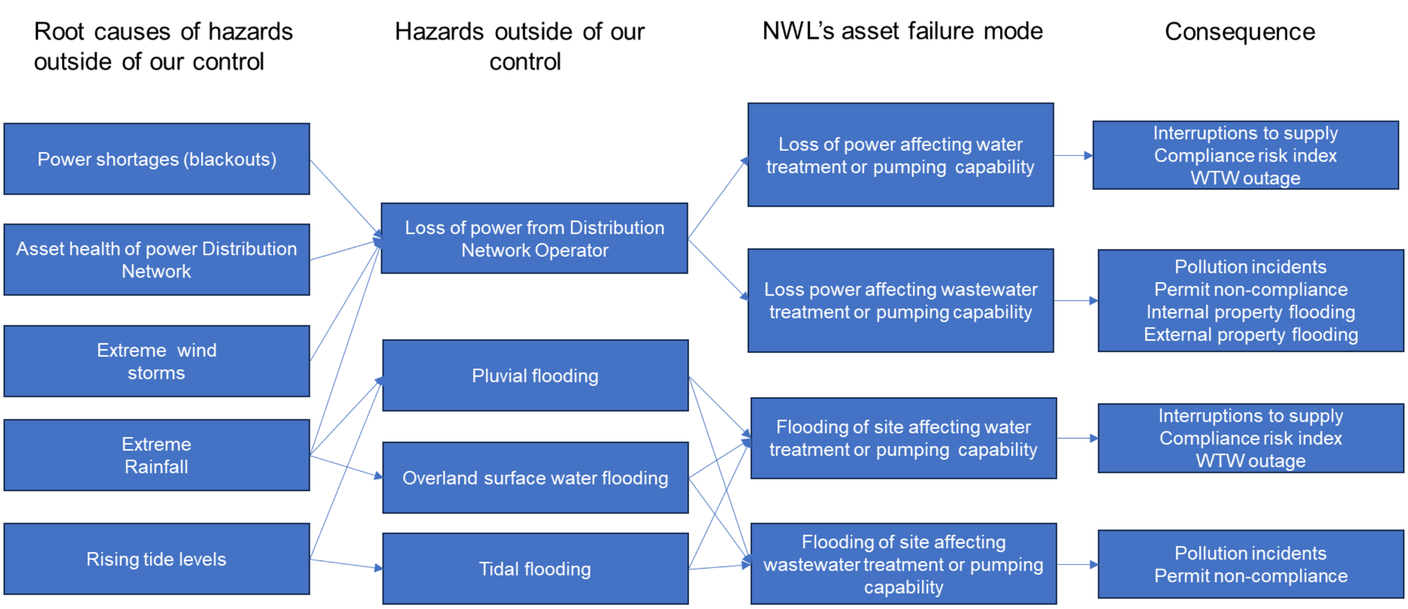
1. INTRODUCTION

Under sections 37 and 94 of the Water Industry Act 1991, water companies have a general duty to develop and maintain an economical system of water supply, making supplies available to those who demand them; and to provide a sewerage system to effectively drain and treat the content of sewers.

Ofwat expects us to incorporate some aspects of climate change into base allowances, but it has also retained a resilience category under enhancement. The refined definition allows companies to request investment to manage increasing risks, or changing acceptance/acceptability of risk, from hazards that are beyond their control. It is for investment not covered by other enhancement areas, and for purposes such as "fluvial or and coastal flooding of company assets and… mitigating failures of other infrastructure systems such as power networks"[1].

This business case sets out our plan for increasing the level of resilience at water and wastewater treatment works and pumping stations. It helps us to make sure these can operate in adverse conditions, and so customers continue to receive drinking water. It also allows us to speed up our response and recovery time for wastewater assets, which helps us avoid pollution incidents. Our proposed plan is set in the context of our Long-term strategy (NES_LTDS), so we are addressing only the most critical sites during AMP8. This helps us to manage affordability, as well as meeting customer expectations to address only those issues where there are immediate impacts on services. Figure 1 shows the hazards that are outside of our control, their root cause and how these affect the services we deliver to customers.

FIGURE 1: RESILIENCE HAZARDS AND CONSEQUENCES



[1] PR24 Final Methodology Guidance Appendix 9 Setting Expenditure Allowances

In section 2.7, we explain the work we have undertaken to assess the effects of climate change leading to more frequent and higher intensity storms/wind and rainfall. We are already seeing the impact of winter storms in our Northumbrian Region where widespread damage to the power network during storm Desmond, Arwen and Malik caused power outages resulting in interruptions to supply and pollution incidents.

The results of our analysis (NES52 and NES53) show that in our Northumbrian region, floods are predicted to become significantly more extreme associated with large scale storms, whereas in the Essex and Suffolk, summer convective rainfall will increase, potentially leading to localised flooding. Sea levels will continue to rise, in particular in the South-East, and storm surges will be more frequent, although their intensity will probably remain the same.

Our **Water Resource Management Plans** and our **Drainage and Wastewater Management Plan** include capacity actions to supply water and treat and dispose of sewerage which arise as a result of climate change, and they take climate change scenarios into account in modelling. However, they do not include funding to protect our assets from damage or outage from risks which are caused by climate change, or third party impacts outside of our control.

The majority of our wastewater treatment works and pumping stations currently rely on "response and recovery" in the event of extreme weather. Our water treatment works have a mixture of resilience approaches including "resistance" and "response and recovery". During AMP7, we have invested enhancement expenditure in flooding resilience at water and wastewater sites which have already suffered pluvial or fluvial flooding. At the end of AMP8, we still have 23 water treatment works, six water pumping stations, 15 service reservoirs, 62 wastewater treatment works, and 76 sewage pumping stations which are at risk from a 1 in 100-year event from pluvial/fluvial flooding or a 1 in 200 event from tidal flooding.

Since 2020, there has been an increase in the number of pollution incidents arising from third party power failures in normal operating conditions and in storms. Over the 2020-22 period, in normal operating conditions third party power failure was our largest root cause of pollution incidents at both sewer pumping stations (31%) and wastewater treatment works (18%). This is primarily attributable to the asset health of the Northern Powergrid Network and the difference in service levels regarding interruptions to power supply. To achieve a 30% reduction in pollution incidents in AMP8 as per WISER guidance, we will need to start to tackle the rising number of third-party power failures.

We are already a leading company on pollution incidents performance, and we will meet the WISER target largely from base investment. However, this cannot be achieved if we continue to see a rising number of third-party power failures, which puts significant upward pressure on pollution incidents. The investment to protect our assets from third party power failures has been included as part of this case as this meets the resilience definition and it has not been historically funded from base expenditure models.

In addition to the pollution incidents that occurred from wastewater assets during normal operating conditions, there is also a clear link between loss of power and pollution incidents and outage at water treatment works in severe weather. Therefore, we need to provide a greater level of resilience to extreme weather events, which are outside of our control. In its methodology, Ofwat removed extreme weather exclusions from its definitions of performance commitments and set a clear expectation that water companies should plan to continue providing services even in extreme weather, rather than relying on “response and recovery” (which would impact on performance commitments). This enhancement case supports us in meeting this expectation.

This enhancement business case describes our approach for providing resilient water and wastewater treatment. This is part of our Long-term strategy and a multi-AMP programme. Our proposed programme for AMP8 is shown in Table 1 and addresses our most critical risks to resilience.

TABLE 1: SITES AND LINK TO PR24 DATA TABLES

Description	PR24 Data tables enhanced category	Investment £m
Protection of 4 high criticality water treatment works and 3 water pumping stations from a 1 in 100-year event from surface water or river flooding or a 1 in 200 event from tidal flooding.	Water Network Plus: Resilience	E&S Capex = 0.927m NWL Capex = 0.208m
Protection of 3 high criticality water treatment works and 3 boreholes from power outage associated with severe storm or wind events. We are protecting against a 1 on 10-year event.	Water Network Plus: Resilience	E&S Capex = 7.067m E&S Opex = 0.034m NWL Capex = 4.004m NWL Opex= 0.017m
Protection of 52 wastewater treatment works and 60 sewage pumping stations from a 1 in 100-year event from surface water or river flooding or a 1 in 200 event from tidal flooding.	Wastewater Network Plus: Resilience	Capex = £17.616m
Protection of 27 high criticality wastewater treatment works and 57 high criticality pumping stations from power outage associated with severe storm or wind events or repeat failures from the power distribution network operator. We are protecting against a third-party power failure both in normal operating conditions and extreme weather.	Wastewater Network Plus: Resilience	Capex £58.280m Opex = £0.724m

2. NEED FOR ENHANCEMENT INVESTMENT

2.1. ALIGNMENT WITH RISK AND RESILIENCE PLANNING FRAMEWORK

Appendix 8 – Resilience (NES09) sets out our overall approach to managing resilience in the round. Section 4 of that document describes in full how we have strengthened our 'resilience in the round' framework. We have carried out a comprehensive review of current risks – as set out in our corporate risk register, future high impact/high uncertainty trends – as assessed in our Long-term strategy (NES_LTDS) (LTS) - and their scope to change the current risk landscape and finally evidence of risks beginning to manifest in current performance.

This resilience assessment highlighted several resilience priorities which need to be addressed. One of these priorities was the need to strengthen our approach to identifying and mitigating long term risks especially in relation to climate change. This was identified as a top-rated current risk, a significant impact/uncertainty future trend, with growing evidence of impacts on current performance.

Section 7.2 of that document summarises work we have conducted in conjunction with Mott Macdonald (NES52 and NES53)[2] to assess how climate risks are expected to evolve in future. It assessed the potential for these changing risks to impact our service provision for customers and the environment. A summary of that review is set out in Tables 2 and 3 below.

TABLE 2: MOTT MACDONALD ASSESSMENT OF HIGHEST CLIMATE RISKS WHICH IMPACT NWL SERVICE PROVISION

Hazard	Magnitude of consequences	Future likelihood of the hazard	Future risk level	Comment
Pluvial/Fluvial/ Tidal Flooding	High	Greater	Very high	The risk is assessed as very high for Northumbrian given expected changes in peak flood flows and summer rainfall.
Wind	High	Greater	Very high	The North-East will see an intensification of winter windstorms like storm Arwen and Desmond
Soil moisture deficits	Moderate	Greater	High	The risk is assessed as high as decreases in summer rainfall and increases in temperatures are likely to be smaller than in Essex and Suffolk, leading to lower impacts.

[2] Climate Resilience Contextualisation Report, Mott MacDonald, July 2022

TABLE 3: MOTT MACDONALD ASSESSMENT OF HIGHEST CLIMATE RISKS WHICH IMPACT ESSEX AND SUFFOLK SERVICE PROVISION

Hazard	Magnitude of consequences	Future likelihood of the hazard	Future risk level	Comment
Wind	High	Greater	Very high	The risk is assessed as very high due to the projected intensification of windstorms and the possibility of cascading failures.
Soil moisture deficits	High	Greater	Very high	The risk is assessed as very high given that decreases in summer rainfall and increases in temperatures are likely to be greater than that in the North-East.
Pluvial/Fluvial/ Tidal Flooding	Moderate	Greater	High	The risk is assessed as high given the absence of wastewater assets. To note that the risk of coastal flooding is likely to be greater in the South-East due to higher increases in sea-level and the low-lying nature of the area.

This document sets out the case for enhancement investment to address two of the highest risks identified by this exercise specifically high and increasing risks in relation to flooding and windstorms, with flooding having the potential to affect and disrupt our assets directly with windstorms typically manifesting by disrupting power supplies to our sites.

2.2. FULFILLING EXPECTATIONS FOR RESILIENCE INVESTMENT CASES IN PR24 GUIDANCE

Table 4 explains how we have met the requirements set out in the PR24 methodology.

TABLE 4: EXPECTATIONS FOR PLANS ENHANCING RESILIENCE FROM PR24 METHODOLOGY

Expectation	How this has been met
Clear line of sight between organisational objectives, resilience planning framework, planned level of service and requested investment	Our plan for resilience has been developed in accordance with our company risk and resilience planning framework which aligns risks to our organisational objectives. This is set in the context of our Long-term strategy up to 2050. Our risks are set out in section 2.1.
Clear systematic risk assessment with corporate risk management process and drinking water safety plans. Risk assessments should assess relevant hazards	We have carried out a resilience assessment for each of our sites which considers the consequence, the likelihood, and the vulnerability of a range of hazards related to climate change, loss of power distribution network due by Distribution Network Operator, fire, and malicious damage. We have assessed the impact of controls that are currently in place to mitigate the hazard. Further detail is described in section 2.6.
Investments should be cost beneficial and represent best value	Each of our interventions has been appraised against our benefits framework and has gone through a robust investment appraisal process. Our chosen options take into consideration the feedback from our customer research including affordability. All but two of our interventions selected is cost beneficial and these are marginal cases. Further detail is described in section 3.3.

Expectation	How this has been met
Optioneering should cover all types of mitigations including resistance, reliability, redundancy, respond and recovery.	We have considered a broad range of options which include resistance, reliability, redundancy, response, and recovery. In screening our options, we have considered whether the interventions prevent or reduce the impact of a service impact on customers occurring. Further detail is provided in section 0 and section 3.2.
Companies should be clear how solution options and the preferred option have been robustly assessed and selected. Investments should be prioritised and promoted based on an understanding of the current level of risk and how this changes under the proposed investment and compares to risk appetite of customers and the company's board.	Our process for assessing and selecting options is described in section 3. Our risk appetite is defined in our Risk Management Framework which is regularly reviewed and approved by Board. As per this document we have a low tolerance of any risks which have the potential to disrupt service availability for customers. We know from overarching resilience customer research (2016) that customers are particularly intolerant of service disruptions which are prolonged in duration and/or impact a significant number of customers – and we have made these 2 factors a key part of our site-by-site resilience assessments described further on in this document.
Consideration of partnership approaches to establish that the overall management of the system of risk is efficient and financial contributions appropriately set.	Our plans have been developed in consultation with Northern Powergrid, and it has shared high level interventions, but its plans are not yet developed enough provide specific locations as their regulatory cycle runs from 2028. We have also reached out to UK Power Networks the supplier in our Essex and Suffolk area. In this instance our sites have not yet experienced a power failure due to climate change. We have also worked with the Northumbria Integrated Drainage Partnership to identify 21 drainage communities where we are proposing a flood resilience project and there is another stakeholder opportunity related to flooding proposed in the same area. A lot of these stakeholder proposals are still under development, and it is not yet clear what the NIDP proposed option is. We will continue to liaise through this partnership and there may be opportunities to re-prioritise some of the NIDP areas to facilitate partnership opportunities. Further information is contained in section 3.5.
Potential impacts on common performance commitments should be assessed and where none can be determined material investments should have a customer protection mechanism based on either outcomes or outputs.	Our customer protection mechanisms are described in section 0. Power interruptions and fluvial/coastal flooding of sites can lead to interruptions to supply, pollution incidents, internal/external flooding, water quality/outage issues and an inability to meet permit conditions. All of these have performance commitments.
Companies should be clear on how any resilience enhancement investments interacts with other aspects of its long-term plan and common planning scenarios, and evidence that it has fully explored any synergies. Robust sensitivity analysis should be carried out.	Our DWMP and WRMP include plans to increase capacity to supply water and collect and treat sewerage because of climate change. This business case includes new assets to protect our assets from damage or outage that arises from severe storms, or third party impacts outside of our control and therefore complete separate from our other climate resilience and operational resilience activities. In section 3.3 we explain the sensitively analysis we have carried out for benefits assessment.

Expectation	How this has been met
Interventions could reduce the likelihood of a hazard or reduce its consequence. Investments to reduce the consequence can be more efficient as they can reduce the risk to multiple hazards (for example, remove single point of failure from WS networks can reduce impact of loss of water treatment works due to a variety of hazards – companies should look at this and proportionally allocate costs between base and enhanced).	We are installing fixed generators, flood doors, raising electrical equipment and procuring temporary pumps for the purposes of increasing resilience due to storms or power. These interventions will not reduce other hazards. The interventions do have multiple benefits as shown in section 3.3, but some of these related to avoidance of benefits.

2.3. LINK TO LONG TERM STRATEGY

This investment is needed as part of the 'maintaining resilience' investment area of our **Long-term strategy** (NES_LTDS) (LTS) core pathway. One of our key themes for PR24 is that we will invest in the resilience of our networks, protecting them from the impacts of increasing extreme weather events arising from climate change. This business case covers adaptation for climate change and resilience to power failures which are outside of our control.

This enhancement case builds on our **Climate Change Adaptation Report** to look at the hazards from climate change and how these will affect our assets in future. We are tackling the risks of power failures and flooding now, in 2025-30, because:

- These hazards already have an impact on service levels now. The data presented in section 2.9.5 shows that Storm Arwen led to significant interruptions to supply from high winds, causing power failures across our region (this one event had a very high impact on performance for the year). Many of our pollution incidents are linked to power failures at pumping stations. Many of our sites are already at risk of flooding, and this will increase in the near future.

- Our climate change forecasts show that storms are expected to become more frequent, with more extreme winter windstorms in the future. This means that investments now would not be wasted, as there is little risk that these would be unnecessary (given the high degree of uncertainty for other elements of climate change).

- These enhancements could provide an immediate reduction in risk to service levels. Customers told us that they were cautious about spending money before it is necessary (as the future is uncertain), and that bills need to be kept affordable – but on the other hand, this can prevent costs and problems escalating in future years and a safe, clean, reliable supply of water is a high priority.

We consider the investment in interventions to address these two issues is low / no regret because it is needed under both the benign and adverse Ofwat common reference scenarios for climate change. We consider it is necessary to make this investment in the 2025-30 period to maintain resilience now and over the long term.

We therefore consider this investment is necessary in 2025-30 to deliver our LTS.

This business case does not include investment to increase our resilience to rising temperatures. There are some areas where high temperatures are already having an impact on our processes – and we describe these in the separate climate change resilience enhancement case, NES35 (for water network plus only). But it is not yet clear exactly how temperatures will change, and how quickly, with several scenarios requiring quite different approaches. Although some investment is needed now to manage the impacts of short spells of high temperatures (such as the heatwaves of the last few summers), we do not expect the full impact of temperature increases until 2040.

2.4. OUR PROGRESS UP TO 2025

Our programme for resilience in AMP7 is primarily focused on providing protection to assets from fluvial/pluvial and tidal flooding which have already suffered flooding during severe storms such as Desmond and Eva. Appendix C contains a list of sites for AMP7 delivery. Barsham WTW occurs in both lists but in AMP7 we are protecting the area of the site which is currently flooding – that is, the contact tank – whereas in AMP8, we are protecting the remaining areas of the site which are still at risk of a 1 in 100-year flood.

Table 5 sets out what we have been funded for in AMP7 and what we expect to deliver.

TABLE 5: WHAT WE WERE FUNDED FOR IN AMP7 AND WHAT WE EXPECT TO DELIVER

AMP7 Funding	AMP7 Delivery
Flooding resilience for 141 wastewater sites covered by performance commitment PR19NES_BES27 - Delivering wastewater resilience enhancement programme"	We were funded for 141 sites but we expect to deliver 140 by 2025 as one is a duplicate. 77% of the current programme has been audited as meeting the requirements. 32 sites have further work to undertake to more fully demonstrate/quantify the benefits of the solutions that we have chosen to implement to improve resilience. We will return any money to customers where we have not met the criteria set out within the outcome delivery incentive.
Flooding resilience for too critical to fail sites covered by performance commitment PR19NES_BES24 – Delivering water resilience enhancement programme	We expect to deliver 14 schemes at 8 sites by 2025 – consistent with the funding allowed in FD19. The PR19 enhancement funding is for loss of power and historic flood risks. At the time of writing this business case 94% of the have been audited as meeting the requirements. One out of 14 sites has further work to undertaken to more fully demonstrate/ quantify the benefits of the solutions that we have chosen to implement.

In 2020-25, our ODI will return funding to customers if we do not deliver these schemes. In section 0, we include a similar **price control deliverable** for this enhancement case to return any funding to customers if any of these schemes are not required. This is the right thing to do, as there should be flexibility to reduce the scope if required (and customers should be fully protected in those circumstances).

2.5. NEED FOR INVESTMENT IN AMP8

Using our learning from AMP7, we have created a much stronger process for understanding the location and depth of power and flooding risks, designing appropriate solutions, and challenging ourselves on costs, which are described in the sections below.

We have made a significant step change in our methods for forecasting climate change and the depth of flood water at our assets (this is a sector first); we have been working with the local power company to influence their plans to increase resilience of the power network; and inspecting key sites to validate plans in more detail. Figure 2 sets out the process we have used to develop our needs.

FIGURE 2: PROCESS FOR DEVELOPING OUR NEEDS

Resilience assessment	**Resilience assessment (section 2.6**) We have carried out a resilience assessment to identify the potential hazards and the impact of our assets.
Climate assessment	**Climate assessment (section 2.7 2.7)** We commissioned Mott MacDonald to undertake a climate assessment to understand whether we are more/less at risk than other areas of the country. They have carried out historical analysis to assign metrological weather patterns to each the of hurricanes and extratropical cyclones that have affected our Northumbrian and Essex and Suffolk Regions. Then forecast the likelihood of such extreme weather events to occurring in the future, up to 2050. This considers both the severity and frequency of extreme rainfall, wind events during the summer and winter periods. We have used the outputs of our historical and forward-looking analysis to populate the likelihoods in our flooding and power resilience assessments for sites.
Pluvial/fluvial/tidal flooding assessment	**Pluvial/Fluvial/Tidal flooding assessment (section 2.8)** We have assessed the impact of our sites being at risk of a 1 in 100 Fluvial and 1 in 200 tidal event occurring now and in the future. We have used EA flood maps and Fathom depth data validate our assessment and to understand the impact on individual assets.
Power assessment	**Distribution Network Operator assessment (section** We have assessed the consequence and likelihood of power outages on our sites impacting on our service levels both in normal and extreme weather conditions. Of our current pollution incidents 31% at SPS and 18% at STWs are caused by DNO failure.
Engagement with third parties	**Engagement with third parties (section 3.5)** We have engaged with Northern Powergrid who have advised us that their standards for power interruptions are less stringent than ours, meaning that pollution incidents and interruptions to supply can occur when DNOs are meeting their regulatory standards. They are aware that their asset health of their electricity poles is worse than other areas of the country which can led to a greater level of longer duration power outages particularly during storms. They are not yet able to share specific locations with us as the regulatory periods for RIIO-ED2 price control is from 1 April to 31 March 2028 whereas the Ofwat submission is due in October 2023.

2.6. RESILIENCE ASSESSMENT

For each of our sites we have carried out a resilience assessment building on the approach we used for water sites at PR19. This considers each site's vulnerability to the hazards of flooding (fluvial, pluvial and tidal), fire, loss of power from third parties, extreme weather and malicious damage. Our resilience assessment incorporates data from our historical and forward-looking analysis such as the climate, flooding and power resilience assessments below.

Figure 3 shows the content of our resilience assessment that relates to this enhancement case - that is, for sites with a vulnerability relating to extreme rainfall, pluvial/fluvial/tidal flooding, and loss of power from third parties and wind.

FIGURE 3: OUR RESILIENCE ASSESSMENT FOR SITES

Pluvial Fluvial Flood Assessment (water)
Consequence – numbers of customers affected and duration of interruptions
Likelihood – number of times site has flooded in the past and likelihood of flooding in the future
Vulnerability – the proportion of the site likely to be affected taking into account flood depth relative to height of assets and existing flood control measures.

Pluvial Fluvial Flood Assessment (waste)
Consequence – the number pollution incidents and category (assumed cat 3) and the population equivalent
Likelihood – number of times site has flooded in the past and likelihood of flooding in the future
Vulnerability – the proportion of the site likely to be affected taking into account flood depth relative to height of assets and existing flood control measures.

Power Assessment (water)
Consequence – numbers of customers affected and duration of interruptions, the impact on water quality
Likelihood – number of times an interruption to supply has occurred to due a power failure outside of our control in the past and in the future
Vulnerability – the proportion of the site functionality that would be diminished due to power outage, taking into account existing control measures.

Power Assessment (waste)
Consequence – the number pollution and or flooding incidents, or permit breaches and the population equivalent
Likelihood – number of times the consequences have occurred in the past arising from a power failure outside of our control and the likelihood of them occurring in the future
Vulnerability – the likelihood a power failure will result in an incident taking into account factors time to spill, whether mobile generators an be brought to site in time or site can be accessed in severe weather.

To assess the vulnerability of these sites, we have considered whether the right controls are in place as shown in Figure 4:

FIGURE 4: CONTROLS ASSESSMENT

Reliability
Has the facility been designed or upgraded to continue functioning in the event of a flood or power loss?

Resistance
Is there flood protection currently in place (eg flood barrier, drainage and temporary pumpiing)

Redundancy
Is an alternative power supply in place?
If contingency measures are deployed what is the % of customers remaining without supply back up?

Response and Recovery
Is there an on-site and regularly reviewed plan for flood or power and has this been embedded. Does it take into account the capacity, capability and speed response
Eg deployment of mobile generators, generator points, tankering, clearup, accessibility of site (fallen trees)

2.7. CLIMATE ASSESSMENT

2.7.1 Regional changes in severity of wind

Storms can bring high winds and extreme rainfall. Winter storms, in particular, are more likely to impact larger areas and bring stronger winds. To understand the potential changes in magnitude for storm events, we used UKCP18 regional projects for each UK region to derive Q99.9 values (that is, levels that would exceed 0.1% of the days in the season) for daily precipitation in winter and summer, and daily wind speeds in winter. We also used Q99.9 wind gust speeds for winter from the UKCP18 local projections. We set five categories for wind speed and gusts, based on representative thresholds that might lead to impacts on flooding and power outages.

Figure 5 and Figure 6 below show that wind speed is likely to diminish slightly or remain similar in the South-East (as shown by green). In turn, the **North-East stands out as an area where the intensity of extreme winds would increase the most**, more than in other England regions (as shown in red). The colours in these diagrams reflect the five categories we set.

FIGURE 5: UK REGIONAL PROJECTED CHANGES IN HIGH WINTER DAILY MEAN WIND SPEED[3]

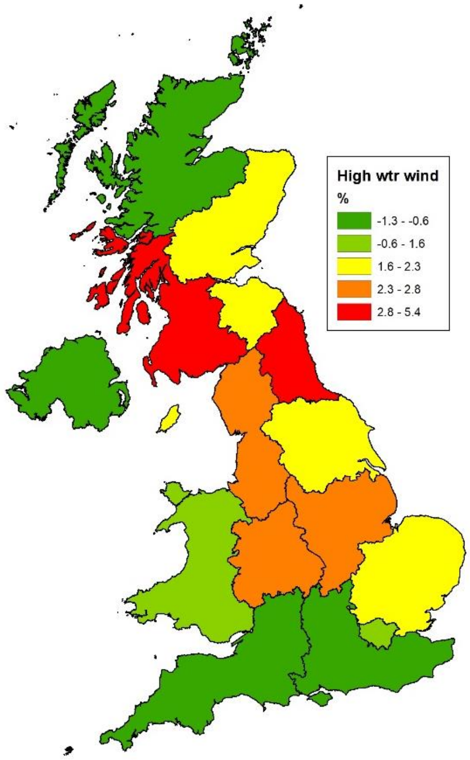
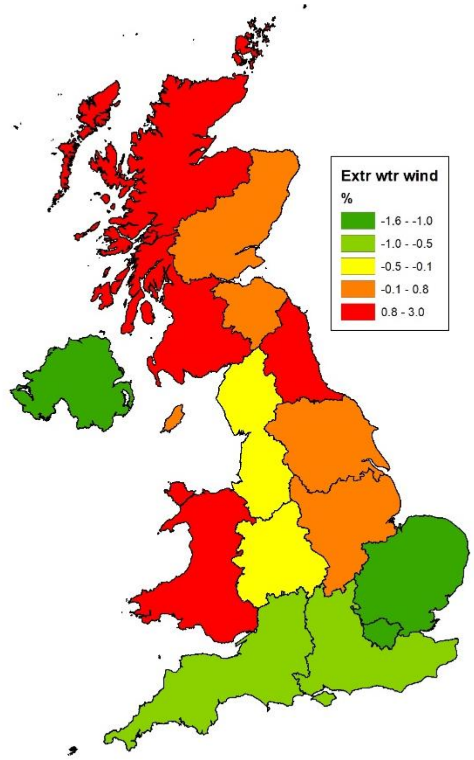


FIGURE 6: UK REGIONAL PROJECTED CHANGES IN EXTREME WINTER WIND GUST[3]



2.7.2 Regional changes in severity of rainfall and floods

Northumbrian Water areas of service appear to be less affected by extreme winter rainfall because they are on the East coast, which reduces the impact of Atlantic storms. However, there would still be noticeable increases in rainfall intensity during this season (Figure 7), in particular in the North-East. The two areas are also likely to be impacted by more intense convective storms in summer (Figure 8), with the North-East standing out. **The combination of stronger extreme wind and more intense rainfall in the winter and summer indicates that the North-East Northumbrian Water region would be particularly susceptible to storms in the future.**

[3] Source: Mott MacDonald analysis of UKCP18 projections

FIGURE 7: UK REGIONAL PROJECTED CHANGES IN EXTREME WINTER DAILY RAINFALL[4]

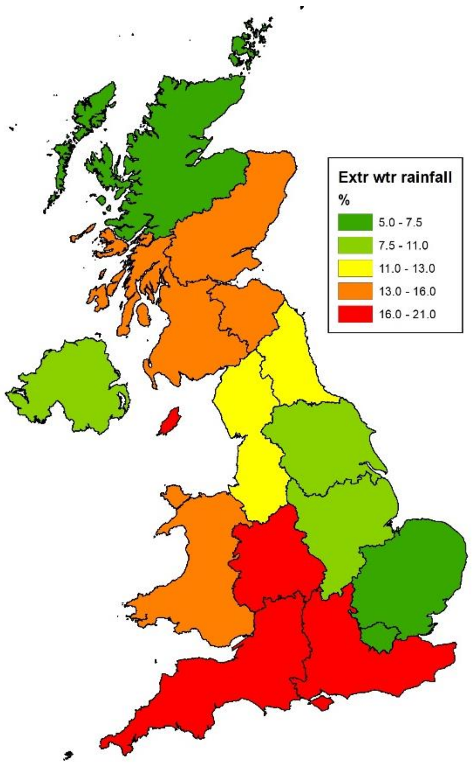
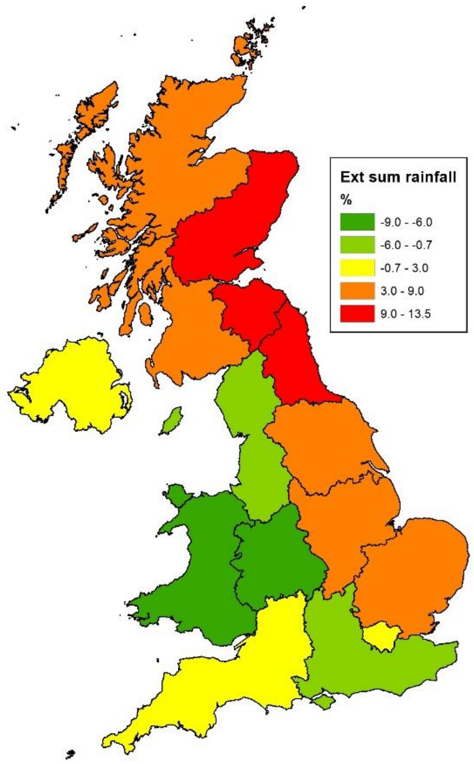


FIGURE 8: UK REGIONAL PROJECTED CHANGES IN EXTREME SUMMER DAILY RAINFALL[4]

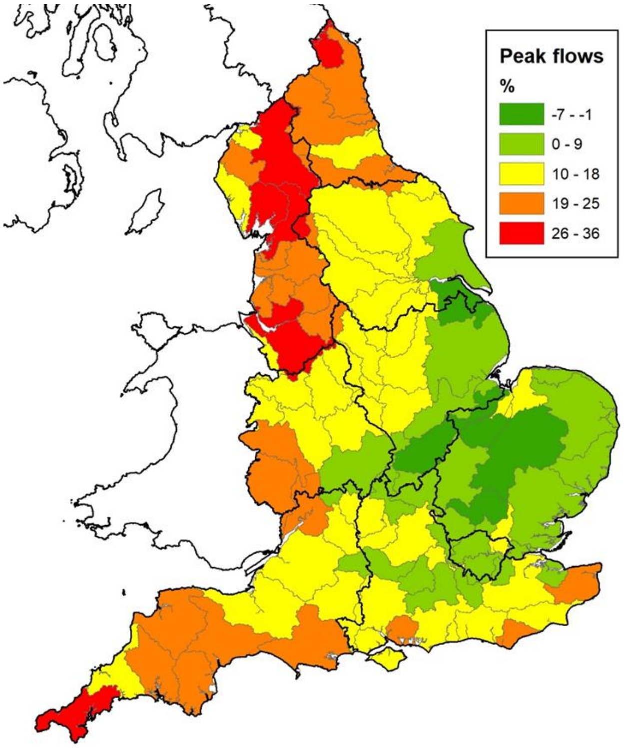


We extracted the Environment Agency climate change allowances for peak flows and reviewed them to establish a country wide comparison of flood risk. Figure 9 shows the projected changes in flood peak flows for EA management catchments which have been obtained by applying regional projections for RCP8.5 to flood hydrology models.

These datasets account for not only changes in rainfall but also for the particular features of the different catchments, such as topography, geology, soil types and land cover. As we carried out the hydrological simulation on a continuous basis, the analysis considered changes in the frequency of storms as well as seasonality, which is relevant to represent soil wetness before the events. The combination of all these factors makes the **North-East Northumbrian Water area very susceptible to changes in floods in the future in comparison with other regions**. In turn, the South-East would experience modest increases in peak flows or even decreases.

[4] Source: Mott MacDonald analysis of UKCP18 projections

FIGURE 9: EA MANAGEMENT CATCHMENT PROJECTED CHANGES IN PEAK FLOWS[5]



2.7.1 Summary of changes of severity of wind and rainfall relative to others

Table 6 shows how our Northumbrian and Essex and Suffolk regions are likely to be more impacted by windstorms, extreme rainfall, and floods outside of our control relative to the rest of the country. Our Northumbrian region is particularly susceptible to climate change impacts on wind and extreme summer rainfall. Extreme winter rainfall would increase as well, which together with the physical properties of the valleys (steep catchments draining from the Pennines, loamy and clayey soils with impeded drainage that are seasonally wet and impermeable geological superficial deposits), would mean that the magnitude of floods would increase more than in other parts of England.

The South-East would not be as impacted by storms, with modest or no increase in large-scale flood magnitudes. However, extreme summer rainfall associated with convective storms is expected to increase more than the UK average, potentially leading to more frequent or intense localised floods.

[5] Source: Environment Agency

TABLE 6: SUMMARY OF CLIMATE HAZARDS IN COMPARISON TO THE REST OF THE COUNTRY

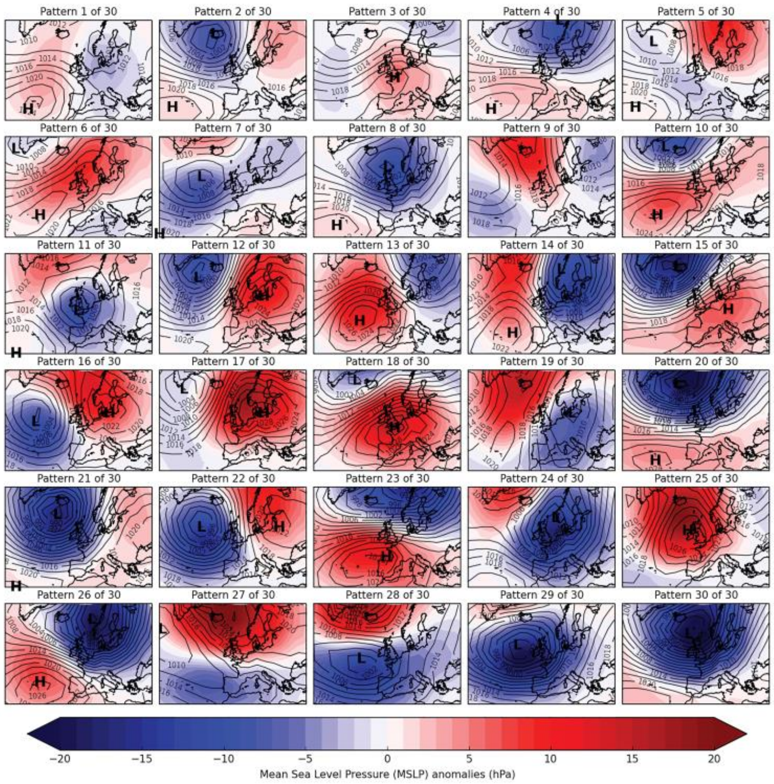
Hazard	North-East	South-East
Windstorms	Higher	Lower
Winter extreme rainfall	Average	Lower
Summer extreme rainfall	Higher	Higher
Floods	Higher	Lower

2.7.2 Weather patterns and storms

To assess the frequency and impact of storms on our assets in more detail, we commissioned Mott MacDonald to identify the Met Office weather patterns (atmospheric circulation types) associated with extratropical cyclones and hurricanes which have affected our Northumbrian and Essex and Suffolk regions in the past.

The Met Office have defined 30 of these patterns for the British Isles, each of them associated with specific weather conditions including the occurrence of extreme events. Any atmospheric conditions on a given day can be attributed to one of these 30 weather patterns. As per extreme events, specific events are more likely to happen under certain weather patterns in a specific season. The 30 weather patterns, relating to different patterns of mean sea level pressure anomalies, are shown in Figure 10.

FIGURE 10: MET OFFICE WEATHER PATTERNS



For each of the storms shown in Table 7, Mott MacDonald were able to assign a weather pattern, which has a historical likelihood associated with it. They then interrogated UKCP18 regional projections under RCP8.5 (high emissions scenario) to understand the changes in the frequency of these weather patterns (and as a result in the occurrence of extratropical cyclones and hurricanes) and in their impact on our two regions measured as changes in the intensity of rainfall and wind. Our reports, NES52 and NES53, describe this analysis in more detail.

The report notes that, in Table 7:

- Hurricane Bertha has a weather pattern that is like Storm Alex (30 September to 3 October 2020) and Storm Lorenzo (2-7 October 2019).
- Storm Arwen was one of the most damaging storms in the last decade.
- Storm Eunice was one of the most powerful storms to hit the south coast of England since the Great Storm of 1987, with the strongest ever wind gust recorded in England in the Isle of Wight.

TABLE 7: IMPACT ON PERFORMANCE COMMITMENT ARISING FROM STORMS[6]

Hurricane or Extratropical Cyclone	Date	Area affected	Storm characteristics	Weather pattern	Historical Likelihood (events/yr)	Future likelihood	Future intensity in NWL	Future intensity in ESW
Ex Hurricane Bertha	Aug 14	NE England	High winds Extreme rainfall leading to flooding	24	0.8	4% decrease	39% increase in rainfall 24% increase in wind	13% decrease in rainfall 10% decrease in wind
Desmond	3-8 Dec 15	Northern England	Exceptionally high rainfall	15	3.5	20% increase	7% decrease in rainfall 12% increase in wind	29% decrease in rainfall 11% increase in wind
Eva	23-24 Dec 15	NW England	High winds Extreme rainfall	21	3.5	3% decrease	3% increase in rainfall 4% decrease in wind	34% increase in rainfall 7% decrease in wind
Summer storms	Aug 19		Intense rainfall and high wind	11	4.7	Same	3% increase in rainfall 4% decrease in wind	51% increase in rainfall 5% decrease in wind
Arwen	25-27 Nov 21	Northern England	Exceptionally high winds from North Sea leading to widespread power outages	30	3.9	Same	19% increase in rainfall No increase in wind	8% increase in rainfall 2% increase in wind
Malik	28-30 Jan 22	Northern Europe	Severe winds leading to widespread power outages	26	3.4	9% increase	16% increase in rainfall No increase in wind	25% increase in rainfall 2% increase in wind
Dudley	14-19 Feb 22	Northern England	Wind	30	3.9	Same	19% increase in rainfall No increase in wind	8% increase in rainfall 2% increase in wind
Eunice	18 Feb 22	Essex and Suffolk	Exceptionally high winds leading to widespread power outages	26	3.4	9% increase	16% increase in rainfall No increase in wind	25% increase in rainfall 2% increase in wind
Franklin	20-22 Feb 22	Northern England	Wind	30	3.9	Same	19% increase in rainfall No increase in wind	8% increase in rainfall 2% increase in wind

[6] Source: Mott MacDonald

To ensure all weather patterns leading to extreme events were captured in the assessment, we also reviewed the UKCP18 regional projections of daily wind speed and daily maximum rainfall for two 12km squares centred in Newcastle and Southend. We filtered the time series by season and weather pattern and derived relevant extreme variables. We then ranked weather patterns as a function of these extreme variables in the North-East and South-East and added those ranking relatively high (but not included in Table 7) to the analysis.

Tables 8 and 9 show the weather patterns associated with extreme rainfall for the North East and South East during summer storms. For the North East, results indicate that the number of events leading to extreme summer precipitation would remain the same or increase slightly, whereas for most weather patterns, the intensity of the events is expected to increase, in particular for large scale storms like ex-Hurricane Bertha. This is further evidenced by the number of weather patterns leading to a Q99.9 precipitation in summer greater than 40mm, which increases from 6 to 9 in the 2050s.

TABLE 8: EXPECTED CHANGES IN FREQUENCY OF SUMMER STORMS IN NORTH EAST

Weather pattern	No. events per year			Associated Q99.9 daily precipitation		
	Baseline	2050s	% change	Baseline	2050s	% change
1	11.5	15.8	+38	49.3	49.9	+1
7	7.1	5.4	-23	48.3	53.5	+11
11 (August 2019 storms)	4.7	4.7	0	49.2	50.4	+2
24 (ex-Hurricane Bertha)	0.8	0.8	-4	38.8	54	+39
25	0.9	1.2	+38	49.6	25.0	-50

For the South-East area, the results point to a slight decrease in the frequency of convective storm-type of events (1, 7 and 11), accompanied by significant intensification of their magnitude, where large scale storms would be less frequent but more intense.

TABLE 8: EXPECTED CHANGES IN FREQUENCY OF SUMMER STORMS IN SOUTH EAST

Weather pattern	No. events per year			Associated Q99.9 daily precipitation		
	Baseline	2050s	% change	Baseline	2050s	% change
1	11.5	15.8	+38	32.2	35.8	+11
7	7.1	5.4	-23	30.6	35.7	+17
11 (August 2019 storms)	4.7	4.7	0	27.4	41.3	+51
24 (ex-Hurricane Bertha)	0.8	0.8	-4	30.1	26.9	-13
26	0.7	0.6	-17	41.9	24.5	-42

Projections point towards **more intense summer storms**, whose frequency would not change significantly. The North East would be more impacted by **large scale storms** whereas the South East would be affected by **short convective storms**.

Tables 10 and 11 show the changes in frequency of extreme rainfall for the North East and South East during winter storms. For the North East overall, results indicate a decrease in the intensity of extreme rainfall events, except for storm Arwen type events, and a similar frequency of occurrence. However, looking across the whole set of weather patterns, the number of events leading to a Q99.9 rainfall greater than 30mm would increase from 9 to 16, which would imply a change in the type of winter storms impacting the area.

TABLE 10: EXPECTED CHANGES IN FREQUENCY OF WINTER EXTREME RAINFALL IN THE NORTH EAST

Weather pattern	No. events per year			Associated Q99.9 daily precipitation		
	Baseline	2050s	% change	Baseline	2050s	% change
7	1.6	1.6	+1	35.6	35.0	-2
9	1.2	1.0	-13	42.6	37.0	-13
15 (storm Desmond)	3.5	4.2	+20	23.1	21.4	-7
19	3.9	3.2	-16	45.0	32.3	-28
21 (storm Eva)	3.5	3.4	-1	22.7	23.5	+3
26 (storm Malik, Eunice)	3.4	3.6	+9	26.8	31.2	+16
30 (storm Arwen, Dudley, Franklin)	3.9	3.9	0	25.7	30.4	+19

For the South East, the area can experience more frequent storms, but their intensity would remain similar. Looking across the whole set of weather patterns, the number of events leading to a Q99.9 rainfall greater than 30mm would decrease from 8 to 6.

TABLE 11: EXPECTED CHANGES IN FREQUENCY IN WINTER EXTREME RAINFALL IN SOUTH EAST

Weather pattern	No. events per year			Associated Q99.9 daily precipitation		
	Baseline	2050s	% change	Baseline	2050s	% change
14	2.5	2.5	+2	32.6	34.0	+4
15 (storm Desmond)	3.5	4.2	+20	25.3	17.9	-29
24 (storms Alex and Lorenzo)	2.6	2.8	+5	39.5	28.3	-28
21 (storm Eva)	3.5	3.4	-1	23.4	31.3	+34
26 (storm Malik, Eunice)	3.4	3.6	+9	32.1	39.9	+25
28	3.0	2.5	-17	31.2	34.5	+11
30 (storm Arwen, Dudley, Franklin)	3.9	3.9	0	29.1	31.4	+8

Tables 12 and 13 show the weather patterns associated with extreme wind for winter storms in the North East and South East. For the North East, storms leading to extreme winds are likely to become more frequent and slightly more intense (as measured by wind speed).

TABLE 12: EXPECTED CHANGES IN FREQUENCY IN WINTER EXTREME WIND IN THE NORTH EAST

Weather pattern	No. events per year			Associated Q99 daily mean wind speed		
	Baseline	2050s	% change	Baseline	2050s	% change
14	2.5	2.5	+2	12.0	12.5	+3
15 (storm Desmond)	3.5	4.2	+20	9.3	10.4	+12
23	4.2	4.8	+14	12.6	13.6	+8
21 (storm Eva)	3.5	3.4	-1%	10.1	9.8	-4
26 (storm Malik, Eunice)	3.4	3.6	+9	13.2	13.2	0
30 (storm Arwen, Dudley, Franklin)	3.9	3.9	0	11.3	11.3	0

In the South East, the frequency and intensity of extreme wind events are expected to increase.

TABLE 13: EXPECTED CHANGES IN FREQUENCY AND IN EXTREME WIND SPEED IN SOUTH EAST

Weather pattern	No. events per year			Associated Q99 daily mean wind speed		
	Baseline	2050s	% change	Baseline	2050s	% change
14	2.5	2.5	+2	12	12.7	+6
15 (storm Desmond)	3.5	4.2	+20	8.8	9.8	+11
20	3.5	3.9	+12	11.7	11.8	+1
21 (storm Eva)	3.5	3.4	-1%	9.1	9.2	+1
26 (storm Malik, Eunice)	3.4	3.6	+9	13.1	13.3	+2
30 (storm Arwen, Dudley, Franklin)	3.9	3.9	0	12.7	13.0	+2

2.7.3 Summary of changes to severity and frequency of wind and rain in our area

Table 14 summarises the changes in severity and frequency of rainfall we expect to see in our areas. Winter storms leading to extreme rainfall will intensify less than summer ones and will be slightly more extreme in the North-East. Their frequency is likely to remain the same or increase slightly. However, extreme windstorms will become more frequent in winter and more intense. This is consistent with the regional analysis presented in Section 2.7.1.

TABLE 14: SUMMARY OF CHANGES IN CLIMATE HAZARDS IN OUR AREA

Hazard	North-East Severity	North -East Frequency	South-East Severity	South-East Frequency
Windstorms	Increase	Increase	Increase	Increase
Winter extreme rainfall	Slight decrease except for Arwen type events	Same	Same	Increase
Summer extreme rainfall	Increase	Slight increase	Significant Increase	Decrease

2.8. PLUVIAL/FLUVIAL/TIDAL FLOOD ASSESSMENT

We have made significant changes to the way that we assess flood risk. These methods reflect the best in class based on a range of available data sources which include:

- Fluvial Flood Risk (undefended): Environment Agency Flood Map for Planning Flood Zones 2 and 3 (1 in 1000-year and 1 in 100-year, respectively)
- Fluvial Flood Risk (defended): Environment Agency 'Long term flood risk maps for rivers and the sea' including layers associated with High (up to 1 in 30yr), Medium (30yr to 100yr), Low (100yr to 1000yr) and Very Low (>1000yr) risk.
- Pluvial Flood Risk: Environment Agency 'Long term flood risk maps for surface water', including layers associated with High (1 in 30yr), Medium (1 in 100yr) and Low (1 in 1000yr) risk.
- Tidal Flood Risk (undefended): Environmental Data WMS Service layers for "Coastal Flood Boundary Extreme Sea Levels", including present day 1 in 200 year and 1 in 1000-year levels.
- Tidal Flood Risk (defended): Environment Agency 'Areas Benefitting from defences' dataset and "NCERM-2018 Tidal Defence" layer.
- Fathom UK Flood Hazard data at 10m spatial resolution for a selection of water and wastewater assets

Our analysis draws on the outcomes of a flood risk assessment carried out by Stantec and reported in a separate technical report[7]. This sets out the number of priority sites that would be flooded, on average, once every 100 years and once every 1,000 years in current conditions from different sources of flooding: fluvial, pluvial, and tidal (1 in 200 years). It also includes an assessment of which assets on a site are likely to be affected. A hydrological assessment concluded that the 1 in 1,000-year flood could be considered as a good proxy for the 1 in 100-year flood in the 2050s once the impact of climate change for the high emissions scenarios is accounted for.

[7] NWG PR24_Climate Change Risk Assessment_Flood Risk Technical Methods and Results (Stantec, Oct 2022); available on request

We included 735 priority sites in the pluvial/fluvial analysis. We present the number of sites flooded in current and future (2050) conditions for a 1 in 100-year event in **Error! Reference source not found.**Table 15. In the case of fluvial f looding, we considered two scenarios: undefended (not protected by Environment Agency flood defences), assuming current flood defences are not maintained, and defended.

TABLE 15: NUMBER OF WATER AND WASTEWATER ASSETS FLOODED IN A 1 IN 100 YEAR EVENT FROM FLUVIAL AND PLUVIAL SOURCES

	Fluvial Undefended Present	Fluvial Undefended Future	Fluvial Defended Present	Fluvial Defended Future	Pluvial Present	Pluvial Future
Water Treatment Works	9	11	10	10	15	24
Service Reservoir	3	3	2	2	10	15
Sewage Treatment Works	57	71	66	72	67	94
Sewage Pumping Stations	64	73	60	73	50	87
Water Pumping Stations	4	5	5	5	3	6

We carried out a similar analysis for tidal flooding, although on a shorter list of 550 priority sites. We present the results in Table 16. We found that no water assets were at risk.

TABLE 16: NUMBER OF WASTEWATER ASSETS FLOODED IN A 1 IN 200 YEAR EVENT FROM TIDAL SOURCE

	Tidal Undefended Present	Tidal Undefended Future	Tidal Defended Present	Tidal Defended Future
Sewage Treatment Works	3	5	1	3
Sewage Pumping Station	8	21	6	19

We then carried out more detailed assessments of the sites initially selected for AMP8 investment, using Fathom UK Flood Hazard data to understand the depth of flooding. We mapped the “centroid” of our assets and obtained flood depth data for a suite of return periods for two future time horizons – 2030 and 2050 – and two climate change scenarios, namely RCP2.6 and RCP8.5 as low and high emission scenarios. This method was only possible for EA catchments of > 50km^2 because anything less than this is not represented in the global fluvial flood models in the Fathom data.

We retained the 100-year standard of protection for analysis and identified the likely flood depth band and return period for each asset. Banding was quite consistent for different time horizons and emission scenarios. In a very limited number of cases (3 out of 122 points), we observed a lower flood depth banding for different time horizons and emissions scenarios, suggesting that designing for a 100-year event would require a similar level of investment whether we looked at a low climate change (RCP2.6) or high climate change (RCP8.5) trajectory. A large proportion of the sites would experience flood depths above 1m and in several cases, above 2m.

We started with an initial list of 302 sites at risk of a 1 in 100 flood risk in 2050. We then split this into a programme to tackle 249 in AMP8 and 57 sites in AMP9 based on the number of sites which are *currently* at risk of a 1 in 100-year flood risk in 2023 (as these would need to be addressed first).

We developed our final list of needs and sites for 2025-30 through an iterative process – developing solutions, assessing the benefits, and then carrying out a full investment appraisal. We describe this in more detail in section 3.

Throughout the process we removed any needs that were not cost beneficial, so we are planning to invest in 122 sites for AMP8 (a full list of needs is in Appendix B). After 2030, there will still be 180 sites which are at risk of flooding for a 1 in 100-year event in 2050, as shown in Table 17, but some of these sites are not cost beneficial to tackle yet.

TABLE 17: SITES FOR FUTURE INVESTMENTS

	AMP8 investment	Future AMPs investment
Sewage Pumping Station	60	76
Service Reservoir	-	15
Sewage Treatment Works	52	62
Water Pumping Station	3	6
Water Treatment Works	4	23
Total Wastewater assets	**112**	**138**
Total Water assets	**10**	**42**
Total	**122**	**180**

2.9. POWER RESILIENCE ASSESSMENT

2.9.1 DNO Context: Northern Powergrid

As part of developing this enhancement case we have engaged with Northern Powergrid, our local distribution network operator in the North East. This has identified two key risks that we must consider when deciding to improve our power resilience:

- The asset health of the Northern Powergrid Network.
- The differences in service levels set by Ofgem and Ofwat for levels of service.

During our discussions with Northern Powergrid (NPg), it confirmed it has an extensive overhead network of over 400,000 poles across both licence areas with many of these being in the NPg North East area. Many of these assets are over 50 years old (the 2nd highest in the UK) and have been scored with a high (poor) asset health score, leading to a higher probability of failure. Ofgem also concluded that this was a risk in its final report on the review into the network's response to Storm Arwen.

During our discussions with Northern Powergrid, it also confirmed that Ofgem's service level agreements allow companies three minutes before a "power outage" is recorded as an interruption, with anything less than three minutes defined as a 'Short Interruption'. Their fault detection is not straight forward as there is no system which accurately pinpoints the exact location where a fault has occurred. Customers also routinely report fault locations as they are observed, but this data tends to be incomplete during widespread outages making full assessment of the network issues encountered more challenging.

NPg shared outage information with us, linked to the meter point administration number of our assets. This confirmed a history of 1,500 power faults at wastewater sites and 1,000 faults at water sites over the last 5 years. This information showed that 57% of power outages affecting our assets were greater than 30 minutes, 23% were between 10-30 minutes and 20% were between 3-10 minutes. NPg does not record outages of less than three minutes, but outages of less than one second can cause Northumbrian Water (and other water companies) to lose site operation and visibility which can trigger interruptions to supply and pollution incidents.

Ofgem currently makes allowances for the impact of severe weather on cost and service performance, and grants both a service exemption in relation to interruptions and a means of claiming additional costs in relation to severe weather impacts on DNOs, as shown in Table 18 below.

Conversely, Ofwat proposes to remove similar exemptions in relation to its supply interruptions metric for the water industry. The Environment Agency also do not accept power outages as a reason to allocate a pollution incident to a third party (such as Northern Powergrid) or to exclude them.

This means that DNOs are not incentivised to fully mitigate against the risk of either short duration power outages, or outages associated with extreme weather events. Both have the potential to disrupt our service provision, and we have shown that this has happened many times in the past. We are therefore exposed to a significant risk in relation to power supply resilience, and we will no longer have any scope to seek an exemption.

We note that **cascading failures are one of the key risks** identified by the Climate Change Committee, and we are expected to take account of these risks in our adaptation responsibilities.

TABLE 18: OFGEM'S EXEMPTION / FUNDING MECHANISMS TO ACCOUNT FOR SEVERE WEATHER[8]

	Severe weather 1-in-20 year funding mechanism[49]	*Exceptional Events exclusions for planned interruptions target[50]*
1. What performance area is being monitored? (e.g. service performance, cost over/underspend, volume risk)	*Totex cost performance*	*Planned interruptions service performance and associated financial incentives ("Interruptions Incentive Scheme")*
2. Which risk is linked to the performance area? (e.g. wind storms, cold snaps, other extreme events)	*Severe weather events*	*Severe weather events and other exceptional events*
3. How the "extreme event" is defined: (e.g. based on a declaration by someone (e.g. the Met Office), triggered by a particular metric (e.g. recorded wind speeds)	*A severe weather 1-in-20 year event is classified as an event where a DNO experiences 42 times its mean daily faults within a 24-hour period.*	*Severe weather is defined as eight times the daily average number of faults at High voltage networks and above.* *Other exceptional events are defined as risks that are genuinely unusual or rare occurrences that are not a function of day-to-day network operations and which Ofgem would not expect networks to be fully resilient to*
4. How is the risk shared? (e.g. partial or full sharing with customers, exclusions or suspension of performance monitoring, partial or full re-opener, allowance for cost pass-through)	*In the event of a 1-in-20 year storm, efficient costs associated with the event are reported and trued-up in the next charging period.*	*Performance under the Interruptions Incentive Scheme in these circumstances is excluded to recognise the impact of these events*
5. Why are the risks shared? (e.g. what are the regulator's stated principles for sharing this risk, what are the impacts on incentives)	*Providing DNOs with a fixed allowance for 1-in-20 year storms does not take into account the uncertain nature of these events. Ex-post funding avoids including uncertain spend in baseline allowances, and instead addresses additional costs if they eventuate.*	*The exceptions to the targets ensure that the incentive is consistent with expectations about the level of reliability that is funded under the price control*

Source: Ofgem, June 2022, "RIIO-ED2 Draft Determinations – Core Methodology Document". Available at: https://www.ofgem.gov.uk/sites/default/files/2022-06/RIIO-ED2%20Draft%20Determinations%20Core%20Methodology.pdf

[8] Source: RIIO-ED2 Draft Determinations – Core Methodology Document, Ofgem, June 2022

2.9.2 Impact of third-party power failures on water treatment assets and pumping stations

We followed a three-stage process to assess power resilience identify needs and develop the list of sites that need investment:

- A **desktop exercise** to compile a long list of (60) sites where there might be a need for improved power resilience.
- A power resilience **vulnerability assessment** which undertook a more comprehensive assessment of the likelihood and consequence of a power outage at each site on the long list, and in so doing identified a short list of the 30 sites at greatest risk.
- **Optioneering and CBA**, as set out in Section 3, applied to each site on the short list, which identified a final list of 6 sites where it is cost beneficial to strengthen power resilience.

Desktop Exercise - we used a range of available evidence to compile a long list of sites including site criticality; current availability of fixed backup power generation; history of site outages, especially during recent severe weather events; and a stakeholder review with operational teams.

Site Vulnerability Assessment - this considered the following factors for each site to identify the highest risk sites:

- Frequency of power outages in past five years.
- Impact of power outage on site functionality.
- Presence of any current site controls to mitigate the effects of power outage.
- Potential time each site would be out of service in the event of an outage / potential restoration time.
- Population served by each site and the proportion of that population likely to be impacted in the event of an outage.

2.9.3 Impact of third-party power failures on pollution incidents

At present, 10% of our wastewater treatment sites and 2% of our sewage pumping stations have a fixed generator. Since 2020, there has been an increase in the number of pollution incidents arising from third party power failures from Northern Powergrid both in normal operating conditions and in storms. Figure 11 and Figure 12 show that over the 2020-22 period in normal operating conditions third party power failure was our largest root cause of pollution incidents at both sewer pumping stations (31%) and wastewater treatment works (18%).

FIGURE 11: ROOT CAUSES OF POLLUTION INCIDENTS FOR PUMPING STATIONS

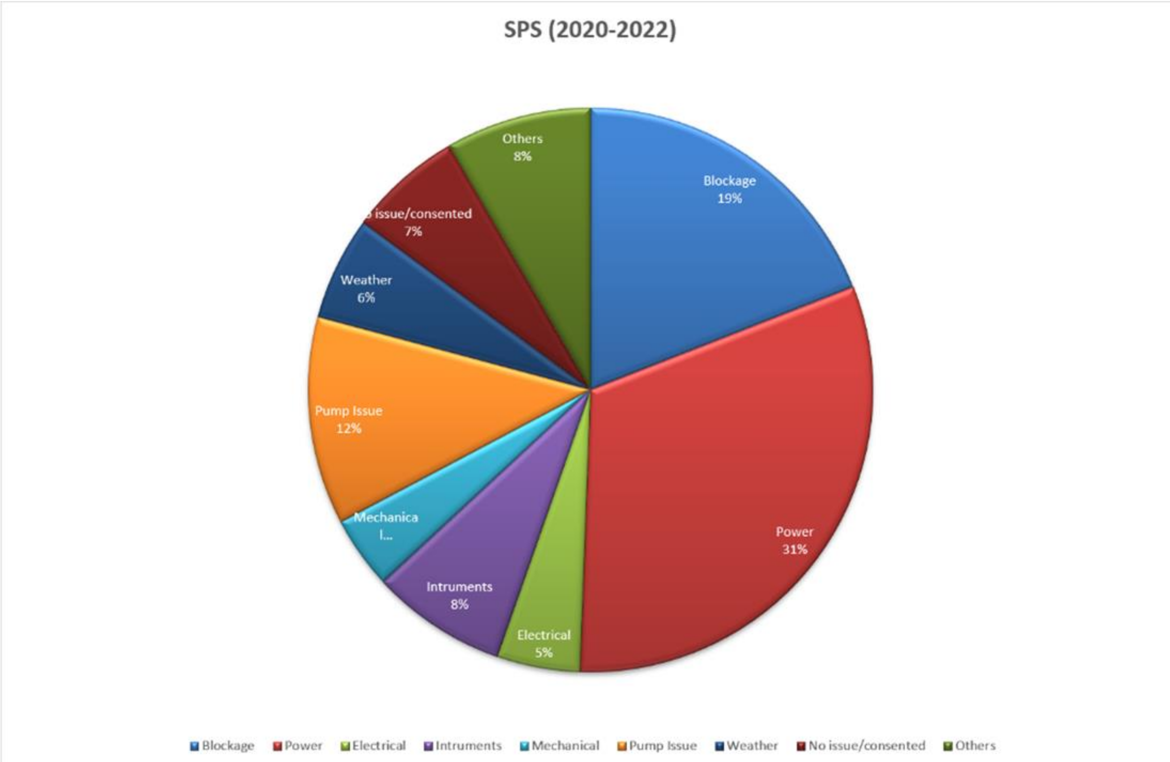


FIGURE 12: ROOT CAUSE OF SEWAGE TREATMENT POLLUTION INCIDENTS 2020 TO 2022

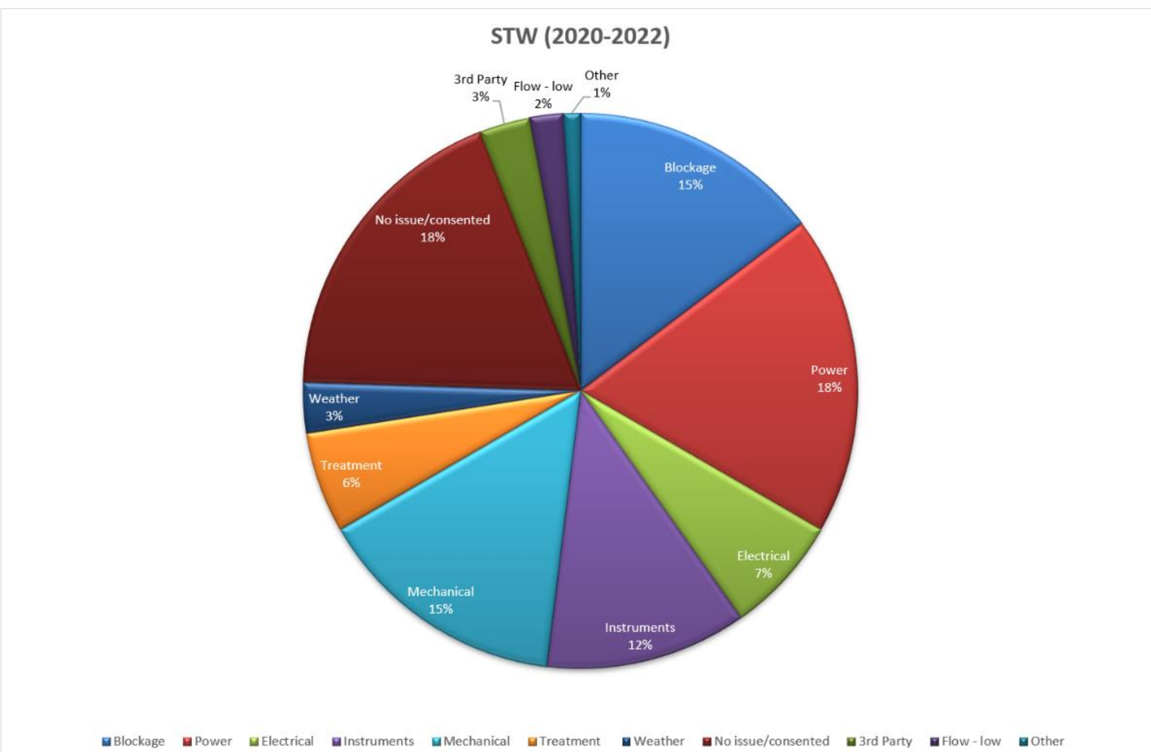
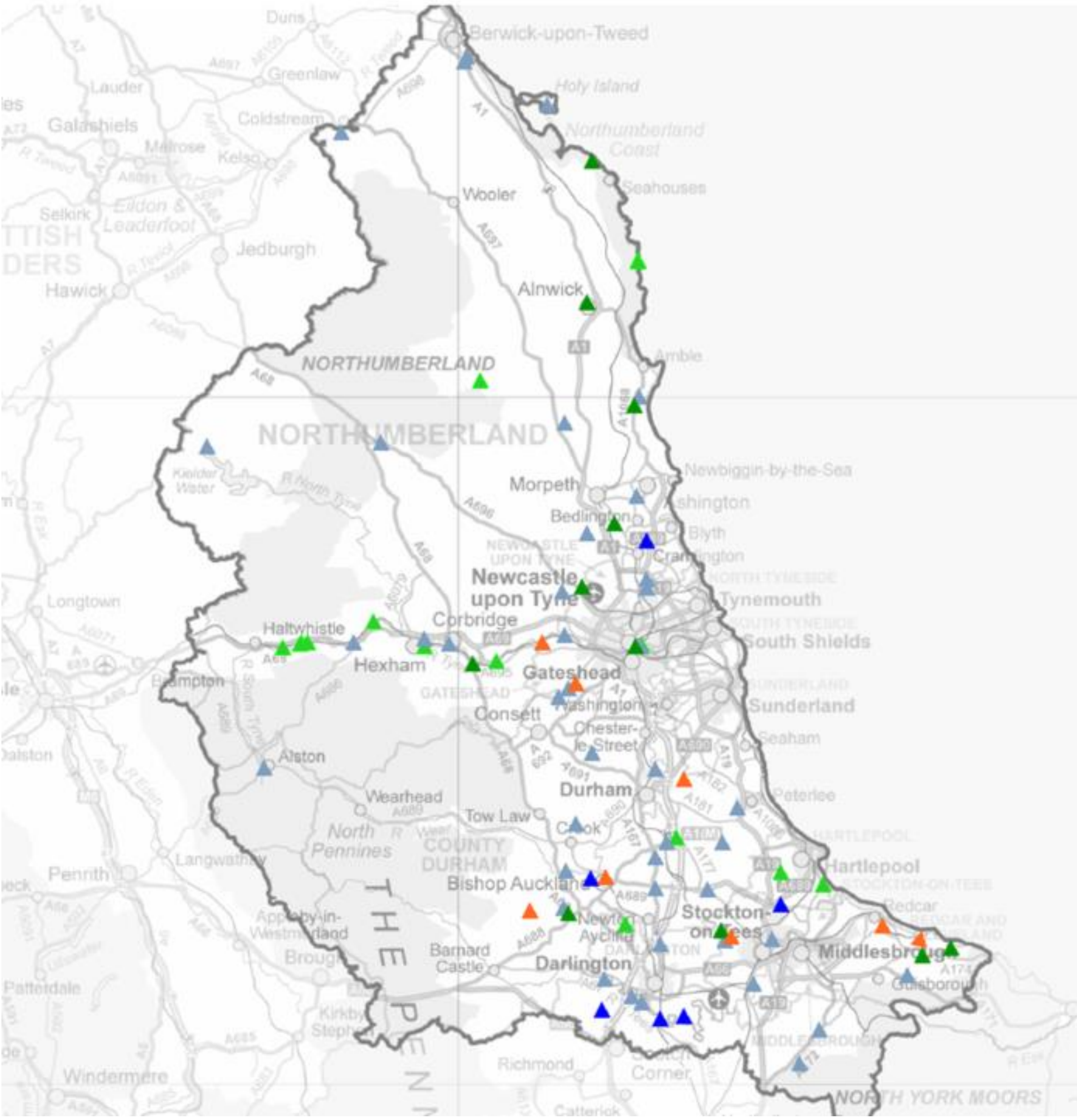


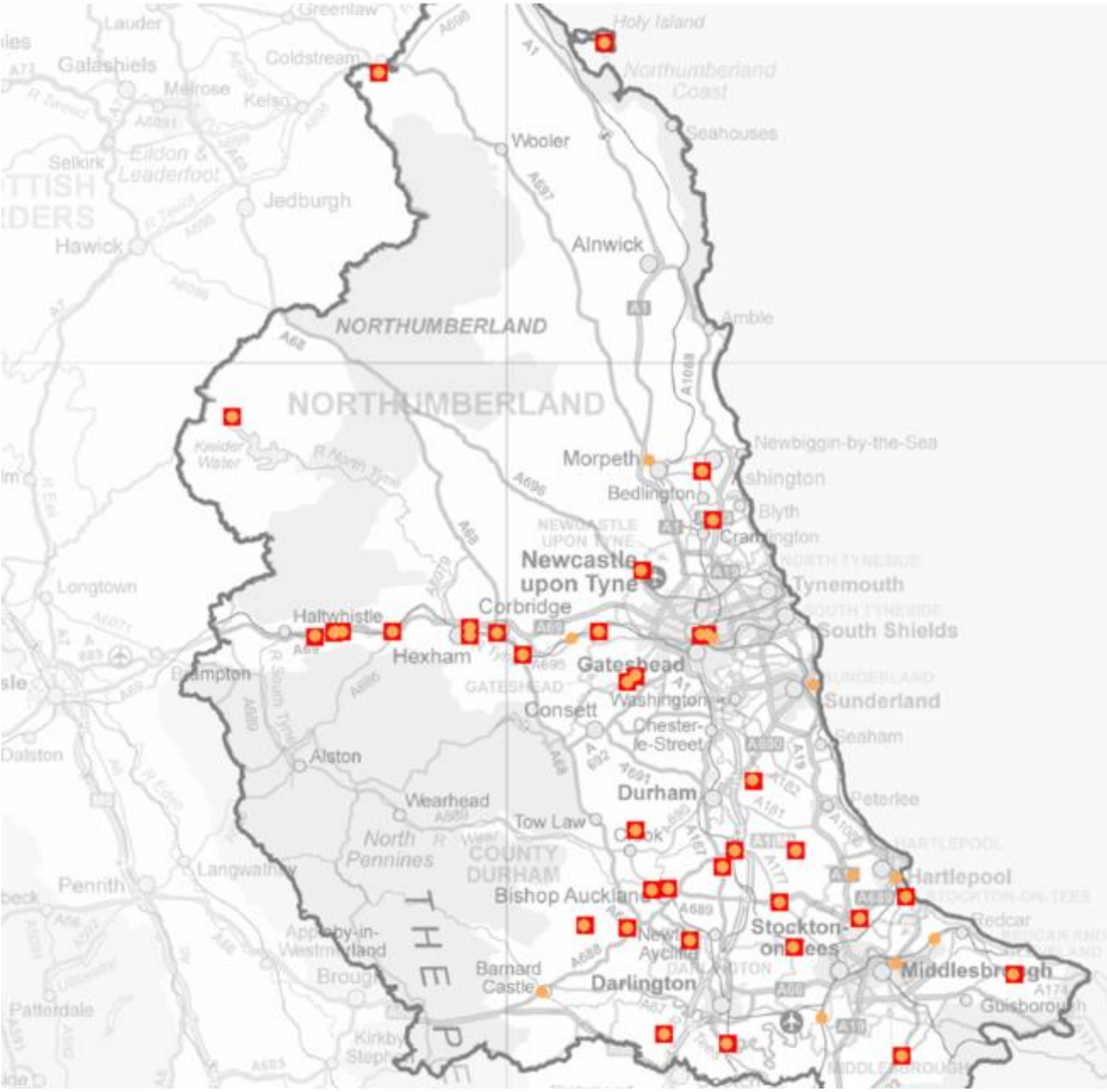
Figure *11* shows that the pollution incidents due to power failures are occurring across our region. The different coloured triangles represent the year in which they occurred. The light green, royal blue and blue/grey occurred from the period 2020-2022, which are demonstrating an increase in frequency.

FIGURE 11: LOCATION OF POLLUTION INCIDENTS DUE TO POWER FAILURES ACROSS OUR NORTHUMBRIAN REGION



The red squares in Figure *12* shows where we have repeat pollution incidents due to power failures. While these maps show there are some locations where repeat power failures are occurring, they also show it is difficult to predict where other failures will occur as they change year on year.

FIGURE 12: LOCATION OF POLLUTION INCIDENTS WITH REPEAT POWER FAILURES



2.9.4 Impact of third-party power failures on pollution performance

To achieve a 30% reduction in pollution incidents in 2025-30 as set out in the WISER guidance, and maintain resilient to extreme winds, which our climate analysis shows are likely to become more frequent and slightly more intense, then we will need to provide a “resistance” approach to resilience. This is because our “response and recovery” approach is not sufficient to reduce pollution incidents.

As we are unable to predict exactly where a third-party power failure will occur, we undertook an initial resilience assessment for our wastewater treatment and pumping stations which considered the:

- Criticality of the asset or site and the vulnerability of the waterbody it discharges to.
- Size of the power supply.
- Type of treatment process (and therefore how quickly it could recover).
- Time available before flooding or pollution is likely to occur.
- Frequency we visit the site.
- Location of the asset to one of our operational depots (where emergency standby equipment may be available).
- Number of pollution incidents that have occurred due to Northern Powergrid power failures and whether they occurred in severe weather conditions.
- Whether alternative or backup power supplies are in place.

Our two highest priority scoring bands were taken forward. We have developed the final list of needs and sites in AMP8, through an iterative process of development of solutions, assessment of benefits and full investment appraisal as described in section 3. We have included a list of 84 needs which are listed in Appendix B.

2.9.5 Case study for storm Arwen (water and wastewater)[9]

Storm Arwen brought severe winds to the UK between 26 and 27 November 2021, with the Met Office issuing a red warning for wind. Wind speeds were widely reported to reach over 69mph with the highest gust speed measured to be 98mph in Northumberland. According to the Met Office, this was one of the most powerful and damaging winter storms of the last decade[10].

BEIS's Energy Emergencies Executive Committee Storm Arwen Review Final Report[11] also notes that the damage inflicted by Storm Arwen on electricity networks was far more severe in Scotland and Northern England compared to other parts of the country, particularly along the Eastern Coast in regions such as Aberdeenshire, Northumberland, and Yorkshire. 45% of power faults were caused by strong wind and 32% by falling trees.[12] Forestry England estimate that the area of forest impacted by Storm Arwen equates to approximately two years annual harvesting programme (circa 2,000 hectares) across Cumbria, Northumberland, Lancashire, Durham, and Gateshead[13].

Northern Powergrid confirmed that they experienced 750 high voltage (HV) and 750 low voltage (LV) incidents in a 24-hr period across both licence areas, however the majority of these were in the NPg Northeast area. NPg also confirmed that the set standard stated by Ofgem for when severe weather exemptions start to apply is 37 HV faults in a 24-hr period for

[9] Jacobs Review of Northumbrian Water's response to Storm Arwen 13 April 2022 (NES54)
[10] Met Office 2021 'Storm Arwen' Microsoft Word - 2021_07_storm_arwen.docx (metoffice.gov.uk)
[11] BEIS (2022), 'Energy Emergencies Executive Committee Storm Arwen Review'
[12] Ofgem Final Report on the Review into Network's response to Storm Arwen June 2022
[13] Letter to NWL CEO from Forestry England, Forest Management Director, North England Forest District.

the NPg Northeast area. NPg confirmed that it was not just the peak winds that caused many of the issues – but rather, the wind duration that prevented teams from repairing damage until NPg's health and safety thresholds for working at height had returned to acceptable levels, resulting in delays to customer restoration works.

Most faults were on lower voltage lines. The main causes were identified in the BEIS report as being:

- Trees falling directly onto the overhead lines/wooden poles.
- Flying debris bringing down/getting entangled in the overhead lines or onto equipment with the substations.
- Strong winds snapping overhead lines or the wooden poles that support them.
- Ice forming around the overhead lines causing them to break under the weight and additional resistance in the sustained high wind.

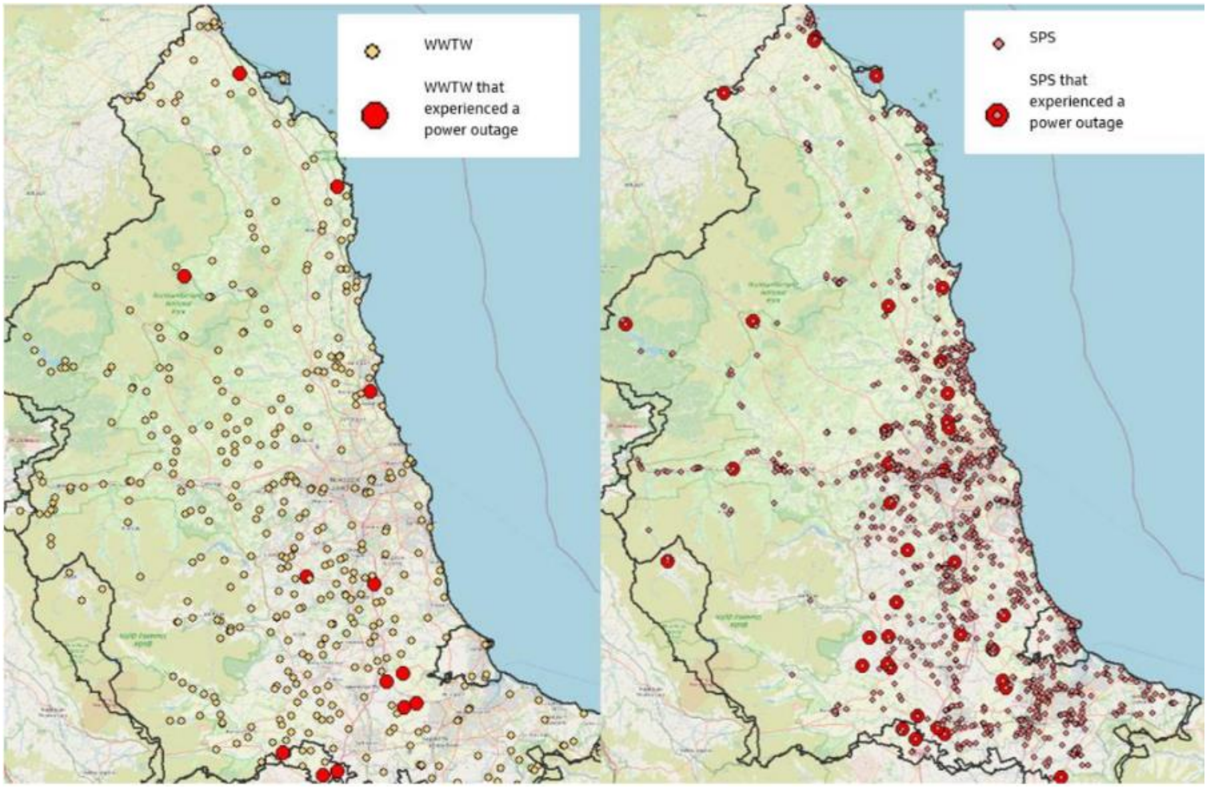
This led to severe consequences on some of our water and wastewater assets:

- Power outages caused shutdowns of some sites. The widescale loss of telemetry and mobile communications between remote sites and the Regional Control Centre meant that understanding the scale and extent of issues was a challenge.
- Loss of power causing sites and assets without on-site generation to fail (water treatment, water pump stations, water reservoirs, wastewater treatment sites and wastewater pump stations).
- For water assets this caused source water production to cease and water in service reservoirs to continue to supply customers until these reserves were exhausted. At this point, interruptions to customer water supplies occurred.
- Water supply interruptions peaked at approximately 8,000 properties at around 14:00 hrs on 28 November 2021. More than half of these interruptions were restored by 2200 hrs on 28 November 2021. By 09:00 hrs on 30 November 2021, interruptions were still being experienced by fewer than 1,200 properties. All interruptions were restored by 12:00 hrs on 7 December 2021.
- For wastewater assets this caused pumps to cease operation, leading to chambers filling and then, potentially, overflowing to watercourses. This resulted in 55 pollutions incidents reported to the Environment Agency.
- Access to sites was also initially disrupted by fallen trees and unsafe travel conditions.

Figure 15 below shows the wastewater sites that experienced power outages during Storm Arwen.

We include our **independent report on our response to Storm Arwen** (NES54) with our Business Plan submission. This concludes that the actions we took were responsive and robust, and that our preparedness was comprehensive. We have reviewed our approach in response to this feedback – but the impacts on our water and wastewater assets, and the associated services to customers, could not have been avoided.

FIGURE 15: WASTEWATER SITES EXPERIENCING POWER OUTAGES DURING STORM ARWEN



2.9.6 Case study for near miss pollution

Our pollution enhancement case sets out the evidence to show we are the most cost-efficient company for wastewater, and we are near frontier performance for pollutions. To deliver a 30% reduction in pollutions in AMP8, we would need to be increasingly proactive in our approach. The following case study shows an example of this.

On 6 June 2023, a significant near miss pollution incident occurred when we lost both high voltage supplies to our largest sewage treatment works at Howdon. Howdon treats final effluent during the bathing water season with UV light and has a permit condition which requires this to be on almost constantly (‘a discharge will have breached its 24-hour dose limit where more than 10 consecutive 15 minutely UV dose measurements fall below 50% of the dose limit specified in its permit’).

On 6 June at 18:48, the two incoming HV feeds to the site failed. National Powergrid have confirmed that this was due to three of the four breakers tripping out and automatically resetting at the NPG network at Flatworth Central Sub Station. As this affected both HV feeds it was not possible switch plant to low voltage and so we had to follow strict health and safety requirements to restore power to the site. Power to the UV plant was restored at 21:13 and lanes 2-4 reached half dose requirements at 21:18. This meant that we were 15 minutes away from a permit breach and a serious pollution incident. Figure 16**Error! Reference source not found.** shows the length of the power outage affecting the UV plant and Figure 17 s hows the dosing period when dosing was not occurring (there are four lanes which require dosing at Howdon).

FIGURE 13: POWER OUTAGE AT HOWDON WWTW ON 6 JUNE 2023

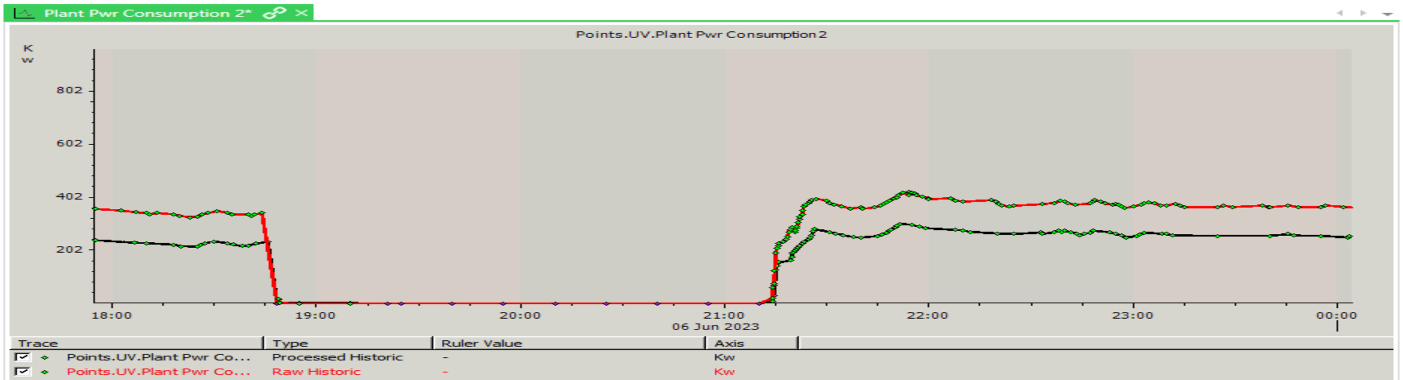


FIGURE 14: DOSING OUTAGE ON UV PLANT ON 6 JUNE 2023

Following this incident, we have identified the need for additional power resilience at our six UV treatment sites which have this type of permit, as we cannot rely on external power supplies.

2.10. Base vs enhancement

Ofwat's PR24 Appendix 9: Setting Expenditure Allowances states that Ofwat are retaining the "other resilience" category under enhancement, but with a refined definition. This means that companies can include investment to manage increasing risks, or changing acceptance/acceptability of risk, from hazards that are beyond their control and not covered by other enhancement areas.

While Ofwat has not provided a definitive list of the hazards that can be included as resilience enhancement, it does state examples such as fluvial or coastal flooding of company assets and mitigating failures of other infrastructure systems such as power networks. Table 19 sets out our assumptions for what we have included within our base and enhancement cases.

TABLE 19: OUR ASSUMPTIONS AROUND BASE AND ENHANCEMENT

Base	Enhancement
Capital and operational expenditure to deliver resilient day to day services. For example, this includes failure of assets which need maintenance. It is expected that there is some improvement in asset health (performance and cost) through good practice asset management and in asset and operational interventions, which contributes to operational resilience.	Manage increasing risks or changing acceptance/acceptability of risk, from hazards that are beyond their control and not covered by other enhancement areas.

Our Water Resource Management Plan and our Drainage and Wastewater Management Plan include capacity actions to supply water and treat and dispose of sewerage which arise as a result of climate change. They do not, however include funding to allow for damage or outage to our assets which are caused by climate change, or third party impacts outside of our control.

We have not included enhancement expenditure for any sites which have been funded under any other AMP8 base or enhanced funding. All assets are new assets, specifically for the purposes of increased power and flood resilience.

2.11. Factors outside of our control

Extreme weather events are outside of our control and can lead to substantial impacts on customers. We commissioned a report from Frontier Economics (submitted in the Ofwat Ideas Lab) which looked at the impact of extreme weather events on ODIs and costs, and suggested how regulators could address these problems.

From 2025, Ofwat will remove extreme weather exclusions from the definitions of some performance commitments – and the EA do not accept power failures as an exclusion for pollution incidents. This increases the exposure of water companies to risks that they cannot control, as they face both the costs of tackling the incident itself, and the regulatory penalty from impacts on service. This risk can be controlled to some extent by creating our own "resistance" to extreme weather events, and so bringing this more within our control.

2.12. CUSTOMER SUPPORT FOR THE NEED

In our **line-of-sight report**, NES45, we note that our **climate change adaptation** report sets out our assessment of climate change and our call to action. Our appendix **A8 – resilience** (NES09) sets out why climate change resilience is a priority for us.

Our water and wastewater systems are vulnerable to shocks and stresses from extreme weather, particularly from storms or increasing heatwaves. These risks are exacerbated by climate change. Although we can tackle some of these risks alone, infrastructure systems are increasingly interconnected and failures in one system can have major impacts on other systems – so leading to major impacts on the economy and people's lives. The National Infrastructure Commission's **Anticipate, React, Recover** report (from 2020) highlights examples of this.

The independent assessment of UK Climate Risk (**CCRA3**) identifies collective risks to systems, particularly the potential for cascading failures – which we experienced during Storm Arwen in 2021, where electricity grid failures led to power outages in water treatment works and pumping stations and so supplies were interrupted to many customers.

The **WISER guidance** identifies the risk of climate change as one of its key challenges, and says that "water companies will need to understand [the impact of climate change] and plan for the long-term across all parts of their business for a range of future climate change scenarios".

The **Government's strategic priorities** expect Ofwat to challenge us to review and understand the current and long-term flood risk to and from our infrastructure and systems, and identify opportunities to increase resilience. Ofwat set climate change adaptation as one of its key challenges for PR24, and the PR24 methodology expects us to "deliver greater flood resilience for their own infrastructure and services".

2.12.1 Evidence from our customer engagement

Our customers have mixed views on adaptation to climate change, with younger customers and customers in our Essex & Suffolk Water area being more supportive of investment in this area (**enhancements and other service area summaries**, NES43).

These mixed views continued through the development of our business plan. In our qualitative affordability and acceptability testing, many felt this was important to avoid future issues and protect future generations. Others questioned if the investment was required, or if other investments would do enough to protect water supplies and quality anyway – and how much impact climate change would have in the UK. The majority of respondents in Essex and Suffolk, and around half of respondents in the North East, selected the "medium" phasing option (used in our Business Plan).

Some customers wanted a higher phasing option, with a perception that investment in this area was happening too late.

Our appendix A8 – resilience (NES09) sets out the evidence and process for our assessment of climate change risks, and our proposed enhancements for 2025-30. This evidence shows that the immediate risks are from increasing storms (which can create flooding and power failures, as experienced in Storm Arwen in 2021, (NES54) and heatwaves (which can affect treatment processes in some areas).

These are similar risks to those identified by stakeholders and the Government. We recognise the importance of tackling cascading failures and have worked with our local electricity company (Northern Powergrid) to identify risks and where we can address these (see section 2.9). We also recognise the need to tackle flooding risks at our assets, which can cause failures at our assets (see section 2.8). These risks are already having an impact.

We developed our plan for climate change adaptation by looking at where:

1. There was a high likelihood that climate change would have an impact on our services in the short or medium term (under any future climate change scenario).
2. This is likely to have an immediate impact on services – in our customer research, we identified supply interruptions from water treatment works and pollution incidents from sewage pumping stations as two of the key areas.

We set these criteria in line with customer views, as they wanted to be sure that the investment was really needed and that we could be confident that the impact of climate change would mean increased risks to services.

We asked our customers about higher investment in 2025-30, to tackle potential future risks – for example, addressing algae growth which can have impacts on water quality, filter performance, and sludge systems at water treatment works. We said that these were less certain, and that we did not think these effects would be seen in the next few years. Some customers did support these investments, but as there were mixed views, we have not included these in our plans for 2025-30.

Most of the effects from increasing temperatures are not likely to be seen in the next few years, particularly where these are effects that build over a long time from higher temperatures (rather than being because of a short period of unusually high temperatures). These forecasts also vary considerably, with lower climate change scenarios not necessarily requiring so much work and the potential for updated climate change assessments to indicate a different risk profile. There are likely to be further unknown mitigations that might reduce the impacts across the wider system, such as: reducing abstraction and restoring river flow; improving river water quality; or improvements in technology. The Water Forum noted that long-term climate change scenarios still had considerable uncertainty and described for example the impact of possible shifts in the Gulf Stream.

This uncertainty suggests that a large investment programme to tackle increases in heat during 2025-30 is not necessary – we have too much uncertainty about the threats from climate change; we do not yet know what specific mitigations would be required; and there has been limited focus on technology to tackle the wider impacts of increasing temperatures on water and wastewater networks. Instead, we will need to focus on understanding these threats and the potential mitigations that will be required, as well as strengthening our innovation focus on this issue. Our appendix **A8 – resilience** (NES09) looks at the impacts of different climate risks in more detail, including heat and raw water quality.

Our customers supported our “medium” option (as included in our Business Plan). This includes investments in flooding and power resilience, as well as process enhancements for water treatment to address specific heat risks that are already happening now.

In our **qualitative affordability and acceptability testing** (NES49), customers supported our ‘preferred’ plan which included these flooding and power improvements. In our **quantitative research** (NES50), 74% of customers supported our preferred plan, including this investment.

3. BEST OPTION FOR CUSTOMERS

Figure 18 shows our process for identifying the best option for customers which is based on the principles of the HM Treasury, The Green Book: Central Government Guidance on Appraisal and Evaluation[14]. A full description of each of the steps and the output is contained in the following sections.

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

FIGURE 15: PROCESS FOR DEVELOPING AND FILTERING OPTIONS

Unconstrained technology options (Long list)	**Unconstrained list of technology options (section 3.2)** We have developed a broad range of potential technology options which consider the 4Rs of resistance, reliability, redundancy and response and recovery.
↓ Screening of technology options (Primary & secondary) ↓ Constrained technology options (Short list)	**Constrained list of technology options (section 3.23.2)** We have screened the unconstrained list of technology option against: 1) The extent to which the intervention provides resilience. 2) Technically feasible.
↓ Apply to individual sites	**Unconstrained list of technology options for site options (appendix B)** We have applied the constrained list of technology options to each of the sites and then screened this to ensure the technology is technically feasible to implement on a specific site.
↓ Options development	**Options development** We have developed scope to level 2. We have taken the learning from our AMP7 delivery. We have surveyed six of the water sites and eight of the wastewater sites, where we have extrapolated our findings to the remainder of the sites. The eight sites contained a mixture of STWs ad SPSs of different sizes. The number of surveys is lower for wastewater as we have taken the learning from the delivery of AMP7 solutions.
↓ Assessment of best value (Investment appraisal)	**Assessment of best value (section 3.3)** We have carried out an assessment of benefits and net present value for each of the options from the constrained list at each site using the Northumbrian Water Value framework and guidance set out in the PR24 Final Methodology Guidance.
↓ Preferred option	**Preferred option (section 3.3)** All sites within our preferred AMP8 plan are cost beneficial except for the Howdon and Bran Sands UV Plants. For power resilience we selected sites with the highest cost benefit ratio as these provide resistance to third party failures and allow us to reduce pollution incidents caused by third party power failure. This provides resistance to hazards.For flood resilience we have selected the least cost options which provide a level of resistance for key electrical equipment and a degree of response and recovery.

3.1. BROAD RANGE OF OPTIONS

3.1.1 Our approach to identifying a broad range of options.

We have developed a broad range of options as shown in Section 3.2. Our options are categorised according to the 4Rs of resilience which is linked to our vulnerability assessment:

- **Resistance** – prevent damage or disruption by providing assets to resist the hazard examples include flood doors and flood embankments.
- **Reliability** – assets designed to operate under a range of conditions include severe weather – examples include water resistant motors which also improve response and recovery times.
- **Redundancy** - Duplicate or provide backup facilities to ensure continuity of service examples include dual supply.
- **Response and recovery** – Fast effective response to recovery from disruptive events examples include generator sockets for mobile generators.

Our broad range of options considers options with differing levels of costs and benefits categorised as follows:

- **Eliminate** – we cannot eliminate the risk as it is caused by the weather which is outside of out control.
- **Collaborate** - work with stakeholders to re-assign the issue or co-fund. Costs can be shared with third parties either to deliver the same or an additional level of social and environmental benefit.
- **Operate** - improved operational management practices to provide increased resilience.
- **Invigorate** - invest in the existing infrastructure to improve performance. These options will provide an increased level of benefit but may be of a lower cost than fabricate options. In this case new infrastructure would be required to meet the standard for secondary treatment, so there are no options for invigorate.
- **Fabricate** - new assets to augment or replace existing. These options are likely to have the highest costs. Green options will have lower carbon and potentially higher biodiversity and amenity benefits. Traditional grey options are likely to have highest certainty that service-related benefits will be realised. Innovative options have the potential for greater benefits and lower costs but have the lower certainty that benefits will be realised.

3.2. PRIMARY AND SECONDARY SCREENING OF OPTIONS

3.2.1 Screening of options for flooding resilience

Table 20 sets out the broad range of options that we have considered for flooding resilience and the type of resilience approach they would deliver. We have screened each of the technology options to determine whether the intervention:

- Will prevent water treatment works or reduce service impacts of interruptions to supply, pollution incidents and sewer flooding occurring.
- Is technically feasible to implement.

TABLE 20: PRIMARY SCREENING OF FLOODING RESILIENCE OPTIONS AGAINST LEVEL OF RESILIENCE AND TECHNICAL FEASIBILITY

Option	Does it prevent or reduce service impacts	Technically Feasible?	Reason for discarding	Resilience approach
Continue business as usual	No	Yes	**Discarded –** does not provide the necessary resilience to maintain service	Response and Recovery
Catchment Adaption – reduce peak flow This would involve collaboration with the EA, Local Authorities and other Stakeholders to look at catchment flood risk at a holistic level and identify opportunities to address flood risk holistically. (This text could fit underneath re Collaboration with EA), any catchment adaption whether on land owned by NWG or not would have to be agreed with stakeholders as listed.	Reduce or Prevent	Yes	**Carried forward for Investigation -** This will require a regional collaboration strategy NWG already work in collaboration with partners such as local authorities through 'Hub' and 'NIDP' Work to address flood risk in this manner is progressing through DWMP and NIDP initiatives, but it will be some time before any understanding of possible opportunities will be realised.	Resistance
Critical Spares Storage To be considered alongside Storm Resilience, concept of storing critical spares/ equipment that can be used across a number of sites in the event of a flood event – this would include: Pumps, Flood Barriers	Reduce	Yes	**Carried forward for Investigation –** This will reduce risk but will require consideration of location and number of spares, training of personnel and ongoing maintenance needs.	Response and Recovery

Option	Does it prevent or reduce service impacts	Technically Feasible?	Reason for discarding	Resilience approach
Enhance existing Resilience Measures There will be local responses to addressing flood risk as teams are made aware of flood event occurring. There will be strategies to minimise impact on site as per Response strategy, these should be reviewed and updated.	Yes	Yes	**Carried forward** – On a site-by-site basis our operational staff are aware of the areas of the sites that tend to flood and what assets are at risk. Measures such as 'sand bags' to minimise risk of ingress to buildings, temporary relocation of critical spares/chemicals to alternate locations within the site and/or planning of the site operations during the period of flood risk to minimise the risk of impact on the works or pollution impact eg maintenance works.	Response and Recovery (base)
Plant Adaption to Operate in Flood This would raise critical electrical control panels and kiosks above predicted flood levels on the site	Prevent	Yes	**Carried forward** Proven technology. Wide water company experience and cost certainty.	Resistance
Flood Embankments and large walls Protection of site from inundation from pluvial/fluvial flooding by construction of flood embankments/walls. By removing this site from functional flood plain, this will increase flood risk to others.	Prevent	Yes	**Discarded** This option is likely to present deliverability challenges esp in relation to land acquisition which are compounded by limited NWL experience of these types of solution	Resistance
Surface water management strategies including SUDS, Strategic Blue/Green corridors This would potentially address risk of pluvial flooding events and should be considered as part of NWG ongoing DWMP strategy of managing catchments and as appropriate considering Surface water separation and SUDS schemes.	Reduce	Yes	**Discarded –** This will reduce the risk but will only progress as part of a strategic review of flood risk within catchments.	Resistance
Site Relocation. This would involve abandoning the existing site and relocation at another location free from pluvial and fluvial flood risk.	Prevent	Yes	**Carried forward under primary screening** **Discarded under secondary screening** Although this option is possible it would be disproportionate in terms of cost and carbon compared to other options and would not be cost beneficial. This would require a lengthy process to investigate possible new sites and lengthy planning and stakeholder management issues to confirm location. Existing treatment and conveyance systems would have to be reconfigured to new site locations	Resistance
Flood prevention Flood doors, sealing, cable and duct entries, raise kiosks, improve sump locations, flood barriers and procure temporary pumps. These interventions seek to protect critical assets on each site.	Reduce	Yes	**Carried forward**	Resistance Response and Recovery

Option	Does it prevent or reduce service impacts	Technically Feasible?	Reason for discarding	Resilience approach
Flood prevention + small walls and coping Flood doors, sealing, cable and duct entries, raise This would raise critical electrical control panels and kiosks above predicted flood levels on the site, improve sump locations, flood barriers, and procure temporary pumps. These interventions seek to protect critical assets on each site. Examples will include raising walls around outside wet wells and chambers.	Reduce	Yes	**Carried forward**	Resistance Response and Recovery

3.2.2 Screening of options for power resilience

We have screened each of the technology options shown in Table 21 to determine whether the intervention:

- Will prevent or reduce service impacts of interruptions to supply, pollution incidents and sewer flooding occurring.
- Is technically feasible to implement.

TABLE 21: PRIMARY SCREENING OF OPTIONS AGAINST LEVEL OF RESILIENCE AND TECHNICAL FEASIBILITY

Option	Does it prevent or reduce service impacts	Technically Feasible?	Reason for discarding	Resilience approach
Continue business as usual	No	Yes	**Discarded –** does not provide the necessary resilience in order to maintain service	Response and Recovery
Identify other power supplier options Identification of smaller power providers in the area such as solar farms, agricultural power generator etc. develop dual feeds with ability to increase in provision in extreme events.	Reduce	Yes	**Carried forward for Investigation** - This will require a regional collaboration strategy to identify other power providers. Not specifically costed at PR24 planning stage but will be reviewed strategically during delivery and implemented where there is a cost/benefit case.	Reliability
Work with Regional Electric Company to identify Power network cable security options Assess vulnerability in supply and undertake work with Distribution Network Operator and other affected parties, for example, to replace above ground power lines with below ground.	Prevent or reduce	Yes	**Carried forward for Investigation –** This will reduce the risk but will require a regional strategy to identify power network vulnerability and feasibility of replacing power lines. This option will be carried forward for Investigation as it will reduce the risk but will require a regional strategy to identify power network vulnerability and feasibility of replacing power lines. Not specifically costed at PR24 planning stage but will be reviewed strategically during delivery and implemented where there is a cost/benefit case. The timing of the regulatory cycle for RIIO-ED2 price control is from 1 April to 31 March 2028 whereas the Ofwat submission is due in October 2023. This makes alignment of the plans very difficult and at this stage.	Reliability
Battery Storage Provision of battery storage to support the site during power outage and also provide balancing power demands for the site. Also benefit to Distribution Network Operator with possible beneficial agreement such as TRIAD, gives site the ability to seamlessly go off grid during grid high power demand.	Reduce	Yes	**Carried forward for Investigation** – Understood that technology is available but not widely implemented and a developing technology. Not costed at this stage as there is limited experience and cost data available as this is a developing /new technology.	Redundancy

Option	Does it prevent or reduce service impacts	Technically Feasible?	Reason for discarding	Resilience approach
Fixed Standby Generator Combustion engine with alternator and transformer providing backup power in the event of an outage.	Prevent	Yes	**Carried forward** Proven technology. Wide water company experience and cost certainty.	Redundancy Reliability
Solar Panels Provide solar panels to provide a resilient power source for the works.	Reduce	Yes	**Carried forward for investigation in delivery** Will only be feasible on certain sites and part resolve a site's power resilience as not guaranteed to produce power 24/7. To be considered in conjunction with other renewable/net zero initiatives.	Redundancy Reliability
Dual HV Supplies Work with Distribution Network Operator to identify alternative grid supplies to provide redundancy in the event of an outage	Prevent or reduce	Yes	**Carried forward for Investigation in delivery–** This will reduce the risk but will require a regional strategy to identify power network vulnerability and feasibility of replacing power lines. This option has not been specifically costed at PR24 but will be considered as part of delivery if it provides a lower cost solution.	Redundancy
Wind Turbines Provide wind turbines at appropriate sites.	Reduce	Yes	**Carried forward for investigation in delivery** Will only be feasible on certain sites and will not provide guaranteed power for 24/7. It will be considered as part of another solution.	Reliability Redundancy
Hydro Turbines Provide hydro turbines at appropriate sites.	Reduce	Yes	**Carried forward for investigation in delivery** Will only be feasible on certain sites and will not provide guaranteed power for 24/7. It will be considered as part of another solution.	Reliability
CHP Combined Heat and Power based on gas turbines/engines at digester works.	Reduce	No	**Discarded** – already implemented at key sites and would likely only partly resolve a site's power resilience issue.	Reliability
Provision of additional mobile generators and updating of contingency plan for generator and tanker availability Regional plan of vulnerable sites and portable generator locations.	Reduce	Yes	**Carried forward** for water and wastewater sites Currently part of the response and recovery plan for all sites **Discarded for large Wastewater UV sites** The permits for these sites say a discharge will have breached its 24-dose limit where more than 10 consecutive 15 minutely UV dose measurements fall below 50% of the dose limit specified in its permit.	Response and Recovery
Critical Spares Storage Identification of critical spares, current facilities. GAP analysis.	Reduce	Yes	**Carried forward** Is necessary as part of an overall power response and recovery strategy	Response and Recovery (base)

Option	Does it prevent or reduce service impacts	Technically Feasible?	Reason for discarding	Resilience approach
UPS for PLC backup Provide Uninterruptable Power Supply – battery backup for vulnerable site's PLCs, to enable a quicker restart of works following a shutdown.	Reduce	Yes	**Discarded:** Does not deliver sufficient resilience benefit	Response and Recovery
Generator Socket Provision of safe and simple plug-in sockets for connection and switch over mains incomers / portable generators.	Reduce	Yes	**Carried forward** Is necessary as part of an overall power response and recovery strategy	Response and recovery
Upgrade Single Phase sites to three phase Provision of 3 phase supplies to sites	Prevent	Yes	**Carried forward for investigation as part of delivery** – Review number of single phase sites that are vulnerable and identify where a 3 phase supply will enhance response and recovery. Not specifically costed at PR24 planning stage but will be reviewed strategically during delivery and implemented where there is a cost/benefit case.	Reliability

For each of the options considered as part of PR24 we have developed and costed four options as part of our enhancement plan:

- Fixed standby generator.
- Mobile standby generator.
- Plug in generator socket.
- UPS for PLC backup.

3.3. BEST VALUE

3.3.1 Benefit Scoring

Our value framework is embedded into our portfolio optimisation tool and contains a mixture of benefits which reflect performance commitments or other social and environmental benefits. First, we score the impact of continuing business as usual and then we score each of the options. Benefits are scored over time for a 30-year time horizon. The scoring considers the certainty of benefits being realised for different types of options. Tables 22 to 25 show the range of benefits, quantification, and monetisation values we have used for the assessment of flooding and power resilience. These include carbon impact (operational and embedded). There are no other natural capital benefits.

For water, we have used private values and the Ofwat marginal benefit of £/unit reduction. For wastewater, the measures are more established, and we have scored using our value measures framework in Copperleaf. In both cases we have included the cost of replacement of an MCC should it be flooded.

TABLE 22: RANGE OF BENEFITS IDENTIFIED FOR WATER FLOODING RESILIENCE

Value measures	Description	Unit	Value	Performance Commitment
Reduced Supply Interruptions	Interruption >24 hrs (population dependent)	£/ event £/ ODI min	Private: £31,820 - £163,303 Societal: £1,810,000 *	Yes
Compliance risk index	Reduction of instances of Drinking Water Inspectorate (DWI) non- compliance: Aesthetic Health Risk	£/ ODI unit score	Private: See row below Societal:£1,660,000 *	Yes
Water Quality Compliance	No. of Network – PCV failure events	£/non-compliance event	£2,162 (0-1000 properties) £2,952 (1001- 5000 properties)	Yes
	No. of Treatment Works – DWI Events		£37,650 (Turbidity failure)	Yes
Improved Water Aesthetics	Cost of improving appearance, taste and smell of water	£/ event £/ ODI contact	Private: £41,766 - £128,588 Societal: £3,690 *	Yes
Reduced Unplanned Outage	Cost of reducing the number of unplanned outages	£/ % ODI score	Societal: £2,660,000 *	Yes
Cost Saving	MCC cost	£	Large population class: £179,324 Medium population class: £89,662 Small population class: £44,831	No
Operational Emissions	tCO_2e/year	Societal £/tCO_2e	£256.2 [15]	Yes – GHG
Embedded Emissions	tCO_2e/year	Societal £/tCO_2e	£256.2[7]	No

[15] £ value per tonne of CO2e in 2025/26, annual increase (varying rate) reaching £378.6/t CO2e in 2054/55

* - While for value rates we typically rely on a comprehensive value model in our copperleaf planning tool, for some measures this is not yet available, so we have used Ofwat's marginal benefit rates.

TABLE 23: RANGE OF BENEFITS IDENTIFIED FOR WASTEWATER FLOOD RESILIENCE

Value measures	Description	Unit	Value	Performance commitment
Improved Treatment Works Performance	Isolated Upper Tier Failure	£/event	£40,979 (250-50,000 population) £52,897 (>50,000 population)	Yes
Reduced Pollution Incidents	Number of pollution incidents.	£/event	Private: £1,738 Societal: £224,187	Yes
Cost Saving	MCC cost	£	Large PE class: £179,324 Medium PE class: £89,662 Small PE class: £44,831	No
Operational Emissions	tCO_2e/year	Societal £/tCO_2e	£256.2[7]	Yes – GHG
Embedded Emissions	tCO_2e/year	Societal £/tCO_2e	£256.2[7]	No

TABLE 24: RANGE OF BENEFITS IDENTIFIED FOR WATER POWER RESILIENCE

Value measures	Description	Unit	Value	Performance Commitment
Interruptions to supply	Interruption >24 hrs (population dependent)	£/ event £/ ODI min	Private: £31,820 - £163,303 Societal: £1,810,000 (1), (2)	Yes
CRI Score	Reduction of instances of Drinking Water Inspectorate (DWI) non compliance	£/ ODI Unit score	Private: See row below Societal:£1,660,000 (1), (3)	Yes
Water Quality Compliance	No. of Network – PCV failure events	£/non-compliance event	£2,162 (0-1000 properties) £6,785 (10001- 20000 properties)]	Yes
	No. of Treatment Works – DWI Events		£37,650 (Turbidity failure)	Yes
Improved Water Aesthetics	Cost of improving appearance, taste and smell of water	£/ event £/ ODI contact	Private: £41,766 - £128,588 Societal: £3,690 (1)	Yes
Reduced Unplanned Outage	Cost of reducing the number of unplanned outages	£/ % ODI Score	Societal: £2,660,000 (1)	Yes
Operational Emissions	tCO_2e/year	Societal £/tCO_2e	£256.2[7]	Yes – GHG
Embedded Emissions	tCO_2e/year	Societal £/tCO_2e	£256.2[7]	No

(1) - While for value rates we typically rely on a comprehensive value model in our copperleaf planning tool, for some measures this is not yet available so we have relied upon Ofwat's marginal benefit rates.

(2) – Significant supply interruptions assumed not to occur at larger sites in the baseline position as these sites would be prioritised for resolution during a major power outage.

(3) – CRI impacts only assumed to occur at specific sites in the baseline position for example boreholes where turbidity levels are especially susceptible to power disruption.

TABLE 25: RANGE OF BENEFITS IDENTIFIED FOR WASTEWATER POWER RESILIENCE

Asset	Value measures	Description	Unit	Value	Performance Commitment
STW/SPS	Reduced Pollution Incidents	Category 3	£/event	Private: £1,738 Societal: £224,187	Yes
SPS	Reduced internal sewer flooding	Event Cost (hydraulic failure)	£/event	£18,501	Yes
		Property Cost (hydraulic failure)	£/property	Private: £13,999 Societal: £27,516	
SPS	Reduced external sewer flooding	Event Cost (hydraulic failure)	£/event	Private: £1,467	Yes
		Property Cost (hydraulic failure)	£/property	Private: £860 Societal: £4,195	
STW	Improved Treatment Works Performance	Isolated Upper Tier Failure	£/failure	£40,979 (250-50,000 population) £52,897 (>50,000 population)	Yes
STW/SPS	Operational Emissions	tCO_2e/year	Societal £/tCO_2e	£256.2[7]	Yes – GHG
STW/SPS	Embedded Emissions	t/CO_2e/year	Societal £/tCO_2e	£256.2[7]	No

In Tables 22 to 25, we explain how we have scored each of the options. The consequence is represented by the value measure, and the likelihood assumes that a consequence occurs. This is derived from the risk assessments carried out in section 2.

TABLE 26: FLOODING RESILIENCE SCORING (WATER)

Value measures	Measure Input	Time Varying?	Value	Comment
Water Quality Compliance	Likelihood[1]	No	1	If failure happens, assumed that non-compliance will occur
	No. Failures/year	Yes	1:30 yrs to 1:100 yrs (baseline) 50% reduction: (Flood Prevention) (1)	Baseline risk aligned with site specific future flood risk from climate analysis
Reduced Water Supply Interruptions	Likelihood[1]	No	1	If failure happens, assumed that non-compliance will occur
	No. Failures/year	Yes	1:30 yrs to 1:100 yrs (baseline) 50% reduction: (Flood Prevention)	Baseline risk aligned with site specific future flood risk from climate analysis
Reduced Unplanned Outage	Likelihood[1]	No	1	If failure happens, assumed that non-compliance will occur
	No. Failures/year	Yes	1:30 yrs to 1:100 yrs (baseline) 50% reduction: (Flood Prevention)	Baseline risk aligned with site specific future flood risk from climate analysis
Improved Water Aesthetics	Likelihood[1]	No	1	If failure happens, assumed that non-compliance will occur
CRI Score	Frequency/year	Yes	1:30 yrs to 1:100 yrs (baseline) 50% reduction: (Flood Prevention)	Baseline risk aligned with site specific future flood risk from climate analysis

(1) – See Table 38 for site-by-site breakdown.

TABLE 27: POWER RESILIENCE SCORING (WATER)

Value measures	Measure Input	Time Varying?	Value	Comment
Water Quality Compliance	Likelihood[1]	No	1	If failure happens, assumed that non-compliance will occur
	No. Failures/year	Yes	0.2: Baseline(1) 0.02: Fixed generator 0.1: Other options	
Reduced Water Supply Interruptions	Likelihood[1]	No	1	If failure happens, assumed that non-compliance will occur
	No. Failures/year	Yes	0.2: Baseline(1) 0.02: Fixed generator 0.1: Other options	Significant supply interruptions assumed not to occur at larger sites in the baseline position as these sites would be prioritised for resolution during a major power outage (2)
Reduced Unplanned Outage	Likelihood	No	1	If failure happens, assumed that non-compliance will occur
	No. Failures/year	Yes	0.2: Baseline(1) 0.02: Fixed generator + Plug In options 0.1: Other options	
Improved Water Aesthetics	Likelihood	No	1	If failure happens, assumed that non-compliance will occur
CRI Score	Frequency/year	Yes	0.2: Baseline (1) 0.02: Fixed generator 0.1: Other options	CRI impacts only assumed to occur at specific sites in the baseline position for example boreholes where turbidity levels are susceptible to power disruption. (2)

(1) - These values are based on a subject matter expert assessment used for CBA purposes of 1 power related site outage occurring in future every 5 years. In Appendix B (Table 35) we undertake analysis to demonstrate that this assumption is conservative compared to a) the data gathered as part of our site-by-site resilience vulnerability assessment and also b) in relation to the expected current and future frequencies of storms which have the potential to disrupt power supplies as per independent climate analysis.

(2) – A site by site breakdown is included in Table 36

The scoring methodology used for wastewater resilience is given in Table 28 and 29.

TABLE 28: FLOODING RESILIENCE SCORING (WASTEWATER)

Value measures	Measure Input	Time Varying?	Value	Comment
Improved Treatment Works Performance	Likelihood[1]	No	1	If failure happens, assumed that non-compliance will occur
	No. Failures/year	Yes	Linear variance between 2025: 0.01 2055: 0.033	Pluvial/Fluvial flooding of 1 in 100 year storm Estimated increase in storm frequency in NWL
Reduced Pollution Incidents	Likelihood[1]	No	1	If failure happens, assumed that non-compliance will occur
	No. Failures/year	Yes	Linear variance between 2025: 0.01 2055: 0.033	Pluvial/Fluvial flooding of 1 in 100 year storm Estimated increase in storm frequency in NWL area
Reduced Sewer Flooding[2] (SPS only)	Likelihood[1]	No	1	If failure happens, assumed that non-compliance will occur
	No. Failures/year	Yes	Linear variance between 2025: 0.01 2055: 0.033	Pluvial/Fluvial flooding of 1 in 100 year storm Estimated increase in storm frequency in NWL area

TABLE 29: POWER RESILIENCE SCORING (WASTEWATER)

Asset	Value measures	Measure Input	Time Varying?	Value	Comment
SPS	Reduced Sewer Flooding[2]	Likelihood[1]	No	1	If failure happens, assumed that non-compliance will occur
		No. Failures/year	Yes	Linear variance between 2025: 0.07 2055: 0.17	From 2021 pollutions/year due to power outages ex Storm Arwen; value with Storm Arwen taken as proxy for future failure with a similar storm
SPS	Reduced Sewer Flooding[2] – due to Northern Powergrid (NPG) drop outs	Likelihood[1]	No	1	If failure happens, assumed that non-compliance will occur
		No. Failures/year	Yes	2025: 0.3 2055: 0.3	Currently, 30% of pollutions per year are due to loss of power to site from NPG. Assumed that will continue to occur
STW/SPS	Reduced Pollution Incidents	Likelihood[1]	No	1	If failure happens, assumed that non-compliance will occur
		No. Failures/year	Yes	Linear variance between 2025: 0.07 2055: 0.17	From 2021 pollutions/year due to power outages ex Storm Arwen; value with Storm Arwen taken as proxy for future failure with a similar storm
STW/SPS	Reduced Pollution Incidents – due to Northern Powergrid (NPG) drop outs	Likelihood[1]	No	1	If failure happens, assumed that non-compliance will occur
		No. Failures/year	Yes	2025: 0.3 2055: 0.3	Currently, 30% of pollutions per year are due to loss of power to site from NPG. Assumed that will continue to occur
STW	Improved Treatment Works Performance	Likelihood[1]	No	1	If failure happens, assumed that non-compliance will occur
		No. Failures/year	Yes	Linear variance between 2025: 0.01 2055: 0.033	Scored as flooding resilience (Table 24) since assumed that power outage will result from flooding incident

[1] Likelihood that failure will lead to a non-compliance event (External Exceedance) or a Pollution

[2] Valid for both Internal and External Sewer Flooding

Each of the options provides a difference level of power resilience. For example, a fixed standby generator will completely mitigate the impact of a flooding or power incident, while an upsized uninterruptable power supply will only have a minor impact on whether the asset remains operational. So, we assigned each of the options a different percentage of the benefit that would be achieved by the installation of the option. The values we considered are as follows:

- Fixed Standby Generator: 100% benefit achieved.
- Plug-in Socket: 30% of benefit achieved.
- Upsized Uninterruptable Power Supply (UPS): 10% of benefit achieved.
- Portable Generator: Two different levels of benefit based on discussion with NWL Site Operators:
  - SPS: 50% of benefit achieved (due to reduced storage at SPS constraining the time to effectively mitigate a site with a portable generator located elsewhere).
  - STW: 70% of benefit achieved.

These values are then used to moderate the number of failures for each value model as given in Table 24 and Table 25. For example, utilising the reduced pollution incident model for a power failure at a STW, in the ‘Do Nothing’ option, the number of failures is 0.07 in both 2025 and 2026 (to two decimal places). For the fixed standby generator option, 100% of benefit is realised in 2026, hence the number of failures reduces to zero. However, for a plug-in socket option only 30% of the benefit is realised, leaving 70% unrealised, hence the number of failures is 0.05.

For flooding, each option provides the same level of resilience and completely mitigate the impact of the flooding; hence the number of failures in 2026 reduces to zero.

3.3.2 Cost benefit appraisal to select the preferred option

For each of the technically feasible options, we have undertaken a robust cost benefit appraisal within our portfolio optimisation tool, Copperleaf, to select the preferred option. This calculates an NPV over 30 years and a cost to benefit ratio for each option. The ratio is calculated by dividing the present value of the profile of benefits by the present value of the profile of costs over the appraisal period of 30 years.

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

For **wastewater power resilience** the full list of preferred options and net present values can be found in Appendix B. We note that the NPVs for 82 of the 84 sites are positive, meaning that the investment is cost beneficial.

The two sites which do not have positive NPVs are the UV plants at our two largest Wastewater Treatment Works, Bran Sands (population equivalent 719,208) and Howdon (population equivalent 823,832). These have NPVs of -£0.426m and -£0.792m. We have still included these sites because:

- The benefits do not capture seasonal bathing water benefits in this assessment, which would improve the NPV.
- We have already seen an incident in June 2023 at one of these sites (see 2.9.6)
- These sites are very large and are greater operational risks (as we would be unable to meet this capacity through alternative sites or storage).
- We have not captured the effects of growth, which would likely turn these NPVs positive (as they are only marginally negative).

We have therefore included these sites with a marginally negative NPV in our enhancement case.

The least cost option would be to provide be to provide an interrupted power supply which would help us to recover our sites more quickly. However, an uninterrupted power supply would help to deliver a reduction in pollution incidents.

The best value option for 77 sites is to install a fixed generator and for seven sites is to install a plug-in socket. We have included a fixed generator as the preferred option for all the sites because these are sites which we have assessed as high criticality and likely to cause a pollution incident should they experience a power failure. We considered mobile generation, but:

- Our sites are often remote and difficult to get to.
- Extreme weather events have impacted lots of sites at once – so although mobile generation has helped protect us from isolated power failure incidents, it is unlikely we would have enough mobile generator capacity in extreme weather.
- Access to sites has been difficult during extreme weather events due to fallen power cables and trees.

For **wastewater flood resilience**, the full list of preferred options and net present values can be found in Appendix B.

The NPVs for all 112 of the sites are positive, which means that the investments are cost beneficial. In all cases our preferred option is the least cost option which does not provide embankments or bunding to the site.

It is not cost beneficial to provide embankments or bunding. This means we will provide site interventions such as flood doors sealing, cable and duct entries, raise kiosks, improve sump locations, flood barriers, and procure temporary pumps. This will provide a level of resistance to protect our electrical equipment, but our response on the rest of the site will remain 'response and recovery'. Protecting the equipment that we have specified will allow our response and recovery to be much quicker.

For **water power resilience** the full list of preferred options and net present values can be found in Appendix B.

The NPVs for all six of the sites are positive, which means that the investment is cost beneficial. In all cases our preferred option is to install fixed generators as this is the only solution that provides resistance and would avoid outage, interruptions to supply and water quality issues should a power interruption occur.

For **water flooding resilience** the full list of preferred options and net present values can be found in Appendix B.

The NPVs for all six of the sites are positive, which means that the investment is cost beneficial. In all cases our preferred option is the least cost option which does not provide embankments or bunding to the site. Provision of embankments or bunding is not cost beneficial.

This means we are providing site interventions such as flood doors, sealing cable and duct entries, raising kiosks, improving sump locations, installing flood barriers, and procuring temporary pumps. This will provide a level of resistance to protect our electrical equipment but our response on the rest of the site will be “response and recovery”. Protecting the equipment that we have specified will allow our response and recovery to be much quicker.

The benefits and investment for our preferred option for is included in Table 30 and Table 31 below.

TABLE 30: INPUTS FOR TABLE CWW15 AND CW15 – BENEFITS BEST VALUE OPTION

Other enhancement	Benefit	Units	2024-25	2025-26	2026-27	2027-28	2028-29	2029-30	Total
	Water Quality Contacts			24.360	376.447	379.768	379.768	379.768	1540.111
Resilience enhancement water Power & Flooding combined (CW15)	CRI			0.000	0.000	0.000	0.000	0.000	0.000
	Unplanned Outage			0.000	0.006	0.006	0.006	0.014	0.032
	Water Supply Interruptions			0.120	0.423	0.423	0.423	0.423	1.812
	Operational carbon	t/CO2e		35.390	136.810	114.723	85.510	66.033	438.466
	Embedded carbon	t/CO2e		2871.060	0.000	0.000	0.000	0.000	2871.060
	Discharge compliance	%		0.000	0.910	0.910	0.910	0.910	3.640
Resilience enhancement wastewater Power & Flooding combined (CWW3)	External flooding	Num		0.000	5.800	5.800	5.800	5.800	23.200
	Internal flooding	Num		0.000	7.620	7.620	7.620	7.620	30.480
	Pollution incidents			0.000	6.480	6.480	6.480	6.480	25.920
	Operational carbon	t/CO2e		316.020	1221.633	1024.350	763.460	589.580	3915.043
	Embedded carbon	t/CO2e		4092.824	4092.824	4092.824	4092.824	4092.824	20464.120

TABLE 31: INPUTS FOR TABLE CWW3 AND CW3 - ENHANCED EXPENDITURE

Other enhancement		2025-26	2026-27	2027-28	2028-29	2029-30	Total
Resilience enhancement water (power) E&S (CW3)	Capex	7.067	-	-	-	-	7.067
	Opex		0.008	0.008	0.008	0.008	0.034
	Totex	7.067	0.008	0.008	0.008	0.008	7.101
Resilience enhancement water (power) NWL (CW3)	Capex	4.004	-	-	-	-	4.004
	Opex	0	0.004	0.004	0.004	0.004	0.017
	Totex	4.004	0.004	0.004	0.004	0.004	4.021
Resilience enhancement water (fluvial flooding) E&S (CW3)	Capex	0.927	-	-	-	-	0.927
	Opex	-	-	-	-	-	-
	Totex	0.927	-	-	-	-	0.927
Resilience enhancement water (fluvial flooding) NWL (CW3)	Capex	0.208	-	-	-	-	0.208
	Opex	-	-	-	-	-	-
	Totex	0.208	-	-	-	-	0.208
Resilience enhancement wastewater (power) (CWW3)	Capex	11.656	11.656	11.656	11.656	11.656	58.280
	Opex	-	0.180	0.180	0.180	0.180	0.720
	Totex	11.656	11.837	11.837	11.837	11.837	59.004
Resilience enhancement wastewater (fluvial flooding) (CWW3)	Capex	3.523	3.523	3.523	3.523	3.523	17.615
	Opex	-	-	-	-	-	
	Totex	3.523	3.523	3.523	3.523	3.523	17.615

3.4. UNCERTAINTY

The options selected as preferred options are the tried and test technologies which have a higher certainty of benefit realisation.

3.5. THIRD PARTY FUNDING

Our discussions with Northern Powergrid are ongoing, but at present no firm opportunities for third party funding have been identified relating to our proposed projects. The regulatory periods for RIIO-ED2 price control are from 1 April to 31 March 2028 whereas the Ofwat submission is due in October 2023. This makes alignment of the plans very difficult and at this stage Northern Powergrid was not able to confirm exact plans to improve resilience across its network or improve areas with frequent power outages. They have a range of system resilience action planned but specific locations are not yet confirmed.

Actions include:

- Completion of all planned essential maintenance on the network in line with legal and statutory obligations.
- Supplement vegetation management works with LiDAR surveys.
- Transition from a simple time-based assessment every 10 years to a condition and risk-based assessment through more frequent inspections on your overhead line pole inspection programme.
- A 5-year programme to rebuild 1,200 km of overhead lines on the HV network and replace some 50,000 poles across all voltage levels.

The following commitments have been made in response to Storm Arwen:

- Increasing the number of dedicated emergency response single home generators.
- Increasing call handling capacity.
- Increased website resilience.
- Revised compensation process.

As we move into delivery, we will continue to share our plans with Northern Powergrid and explore collaborative options to deliver a lower cost to customers. We are jointly committed to ensuring that we provide customers in the North East with resilient services, delivered where possible in partnership efficiently and effectively for the long-term. We are also aware that Northern Powergrid Foundation[16] has provided support to 43 communities worst hit by the winter storms of 2021/22 so they are on their way to become energy resilient during emergency events. We will continue to explore whether there any future opportunities to provide wider benefits to communities.

We have engaged with the Environment Agency and the Lead Local Flood Authorities via our membership of the Northumbria Integrated Drainage Partnership. We have identified 21 drainage communities where we are proposing a flood resilience project and there is another stakeholder opportunity related to flooding proposed in the same area. A lot of these stakeholder proposals are currently under development, and it is not yet clear what the NIDP proposed option will be. It may or may not remove the risk to our assets. We will continue to liaise through the partnership and there may be opportunities to re-prioritise some of the NIDP areas to facilitate partnership opportunities.

3.6. DIRECT PROCUREMENT FOR CUSTOMERS

We assessed the flooding and power resilience programme against the DPC guidance (see our **assessment report**, NES38). This report concludes there are no opportunities for direct procurement for customers relevant to flooding and power resilience because the projects are small value and less than <£200m of whole life totex.

[16] Grants Awarded | Northern Powergrid Foundation

3.7. CUSTOMERS VIEWS INFORMING OPTION SELECTION

We describe our evidence from our customer engagement in **section 2.12**. We did not discuss the specific options for power and flooding resilience with our customers (as these are engineering issues).

However, we discussed the phasing of flooding and power resilience with our customers. For our work on asset health, customers asked for a "hybrid, middle ground" option, that focuses on where we know exactly where work is necessary now, and where this has an immediate impact on service (and safe, clean spaces). This middle ground would be more affordable now, without taking too much risk on problems escalating in future years (**enhancements and other service area summaries**, NES43). We applied this principle to selecting sites for power and flooding resilience too, choosing sites where we know this is necessary now and where this has an immediate impact on service.

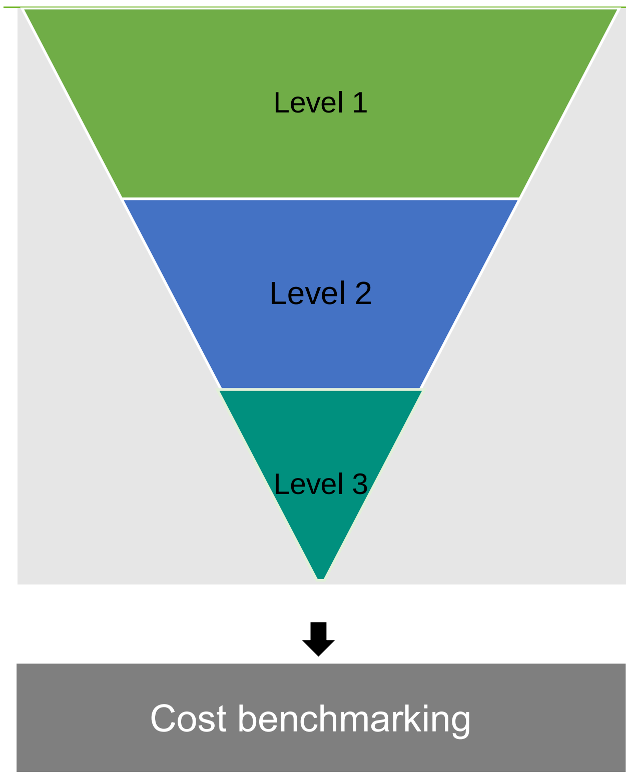
4. COST EFFICIENCY

4.1. APPROACH TO COSTING

4.1.1 Cost methodology

A full description of our costing methodology is contained in Appendix A3 - Costs (NES04) and shown in Figure 19. Our plans for flooding resilience are based on our actual costs of AMP7 delivery This equates to a Level 2 in costing as we have not surveyed every site. Our power resilience is based on our AMP7 delivery and considers the cost of installing fixed and mobile generators and the cost of hiring them. This level is appropriate for a Price Review submission as it is sufficient to understand that the interventions can be delivered within the cost at a programme level. A level 3 estimate would require a level of detailed design to be carried out which would incur significantly more cost which is not appropriate until delivery is confirmed.

FIGURE 16: PROCESS COST ESTIMATION



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

Costing is undertaken using Northumbrian Water's costing curves. Costing occurs at an overall asset level. For example, package plant or a pumping for a certain population.

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

Costing is carried out using our costing curves. Costing occurs for each of the main items of scope. For example, the length of rising main and the size of the pumps.

Level – 3 (confidence: - 20% to +30%)

Detailed bottom-up cost of all items taking into consideration factors such as ground conditions.

Cost benchmarking

We have benchmarked five sites power sites against the available cost curves from other companies.

Our costing has been carried out by our costing partners (Mott MacDonald) using our own iMOD cost models. They have then been benchmarked against our costing partner's cost database and independently assured by PwC and internal audit as they have been loaded into data tables.

4.1.2 Cost benchmarking

We have benchmarked the direct costs for fixed generators against our costing partner's database. For fixed generators our costing partner has benchmarked where it is possible to carry out an equitable comparison against three other companies. A mean average of these companies has been used as the benchmark with a 25% percentile and 75% percentile provided as a suitable range. We have been able to generate 39 data points for fixed generators.

We have selected five projects within this case at varying sizes across the identified range of solution costs to compare against the industry position. Reviewing projects at varying ranges of value allows for interrogation of the costs produced at individual ranges of the curves and price data utilised in costing.

We have benchmarked on direct costs which are directly attributable to the project such as plant, labour material and equipment. We have not benchmarked on indirect costs as there may be a lower level of cost due to this being a "low design" item.

TABLE 32: BENCHMARK OF DIRECT COSTS

Investment Name	Option Type	Northumbrian £	Benchmark £	25%ile £	75%ile £	Delta[17] £	Delta %[18]
Amble STW	Fixed generator	81,970	106,240	93,039	128,413	-24.279	-23%
Cramlington STW	Fixed generator	80,949	105,012	91,933	126,934	-24,063	-23%
Low Wadsworth STW	Fixed generator	60,533	79,871	69,212	96,736	-19,338	-24%
Browney STW	Fixed generator	76,865	100,048	87,485	120,990	-23,183	-23%
Hendon STW	Fixed generator	66,657	87,504	76,164	105,931	-20,847	-24%
Total		**366,974**	**478,683**	**417,831**	**579,005**	**-111,709**	**-23%**

Source: Northumbrian Water

[17] Delta = Northumbrian – Benchmark
[18] Delta % = Delta ÷ Benchmark

When considering direct costs, Table 32 shows we are 23% more efficient overall than our comparators. We have not been able to benchmark the costs of the solutions for flood resilience as these are all minor items which may be directly delivered and therefore do not form part of our costing partner's data set.

4.1.3 Factors affecting cost allowances

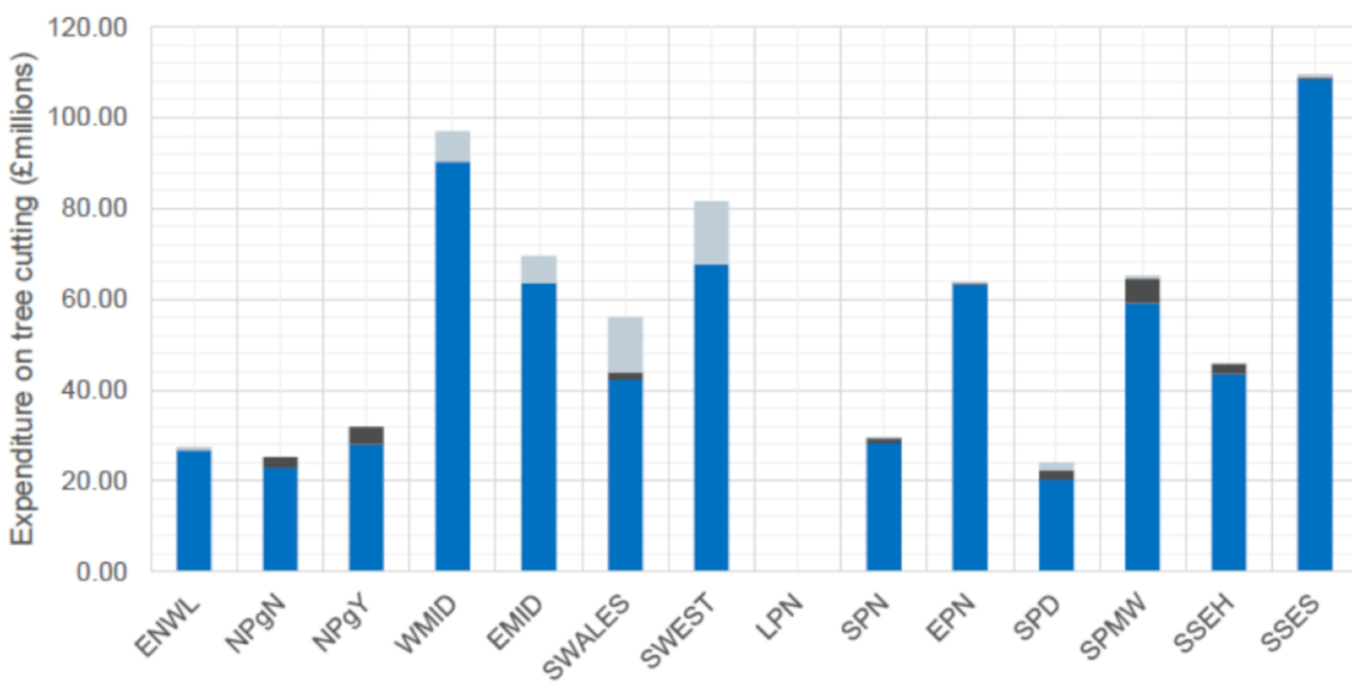
The cost of providing resilience for an individual site is not likely to be different from other companies. However, we are likely to need to provide resilience at a higher number of sites and tackle higher risks of hazards than other areas of the country – and so we need more interventions.

TABLE 33: SUMMARY OF CLIMATE HAZARDS IN COMPARISON TO THE REST OF THE COUNTRY

Hazard	North-East	South-East
Windstorms	Higher	Lower
Winter extreme rainfall	Average	Lower
Summer extreme rainfall	Higher	Higher
Floods	Higher	Lower

BEIS published a report when they reviewed the impact of Storm Arwen[19], which contains analysis to show that Northern Powergrid has spent considerably less than some other companies on their resilience.

FIGURE 17: COMPARISON OF TREE CUTTING EXPENDITURE FOR SAFETY CLEARANCES FOR RESILIENCE PURPOSES



[19] BEIS (2022), 'Energy Emergencies Executive Committee Storm Arwen Review'

FIGURE 18: PROPORTION OF POLES WITH A HIGH PROBABILITY OF FAILURE[20]

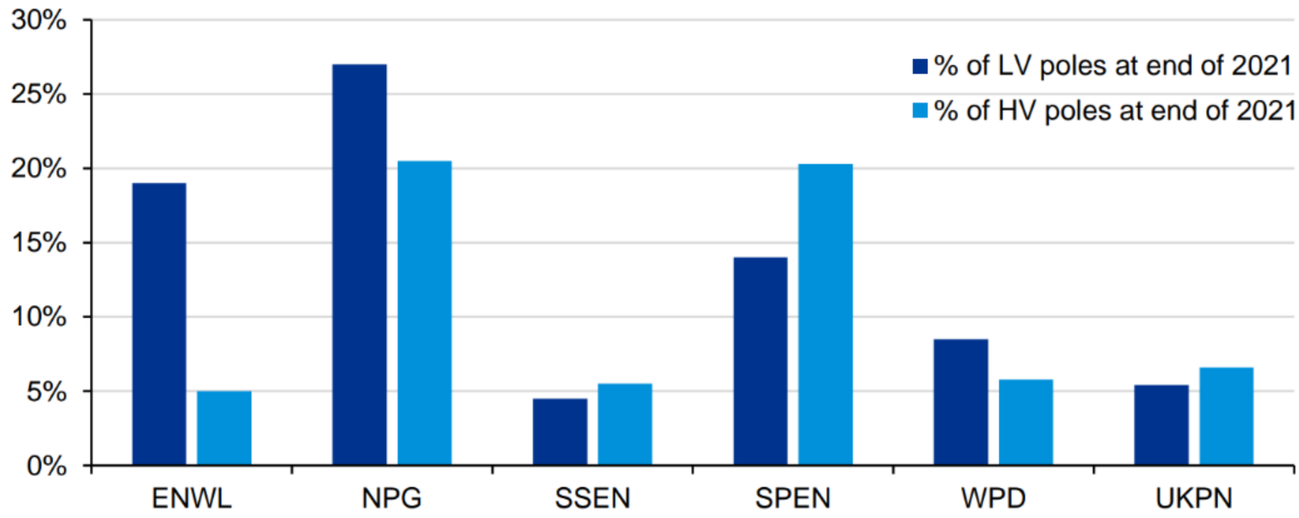


Figure 20 and Figure 21 show that NPG spends less on its resilience, and has a higher proportion of poles with a probability of failure, than other energy DNOs.

[20] Ofgem (2022) Final report on the review into networks response to Storm Arwen

5. CUSTOMER PROTECTION

5.1. PERFORMANCE COMMITMENTS

Third party power failures and fluvial/coastal flooding can result in interruptions to supply, pollution incidents, the inability to meet water quality standards or wastewater permit requirements. So, some protection for customers is provided under these performance commitments. While there have been severe weather exclusions in the past for Category 4 pollutions the Environment Agency is currently consulting on removal of the Category 4 so that all pollutions will be Category 3.

However, if we did not deliver these improvements, this would only have a small impact on ODIs compared to the costs of these schemes.

5.2. PRICE CONTROL DELIVERABLES

Our approach to determining Price Control Deliverables (PCD) is outlined in Section 12.3 of A3 – Costs (NES04). In Table 34 below, we assess our septic tank related enhancements to test if the benefits are linked to PCs, against Ofwat's materiality of 1%, and to understand if there are outcome measures that can be used.

TABLE 34: ASSESSMENT OF BENEFITS AGAINST THE PCD CRITERIA

Enhancement scheme	Benefits linked to PC?	Materiality	Possible outcomes?
Flooding and power resilience (NES31)	Pass – benefits are interruptions to supply, pollution incidents, and others	Pass – >1% of wastewater controls	Outcome difficult to measure, as this relates to a reduction in risk (and might not be realised if extreme weather is not seen in the period).

We propose a PCD based on the unit rate of delivering flooding and power resilience schemes. This is a separate unit rate for flooding resilience and power resilience, as these have quite different unit rates, but we propose a combined rate for water and wastewater solutions together, for simplicity. This would mean a rate of £0.158m for flooding sites (with 119 in total to deliver), and £0.771m for power resilience sites (with 91 in total to deliver).

A summary of our PCD for flooding and power is outlined in Table 35.

TABLE 35: SUMMARY OF THE PRICE CONTROL DELIVERABLE FOR OUR FLOODING AND POWER RESILIENCE PROGRAMME TO PROTECT CUSTOMERS

Description of price control deliverable	Unit rate for delivery of flooding and power resilience interventions
Measurement and reporting	We will report on our progress annually in our Annual Performance Report, as well as reporting at PR29.
Conditions on allowance	Projects must deliver the level of resilience described in this case.
Assurances	We will provide independent assurance with a duty of care to Ofwat to determine our progress, the level of resilience delivered, and expected progress by 31 March 2025. We will provide this with our PR29 business plan.
Price control deliverable payment rate	For each flooding site: £0.158m (119 sites in total to deliver). For each power site: £0.771m (91 sites in total to deliver)
Impact on performance in relation to performance commitments	There are some benefits to performance commitments.

This PCD should not define the exact sites where power and flooding interventions are made – as these might change as we refine our assessments up to 2030, including further site inspections and plans. This should not incentivise us to deliver these interventions if they are not required.

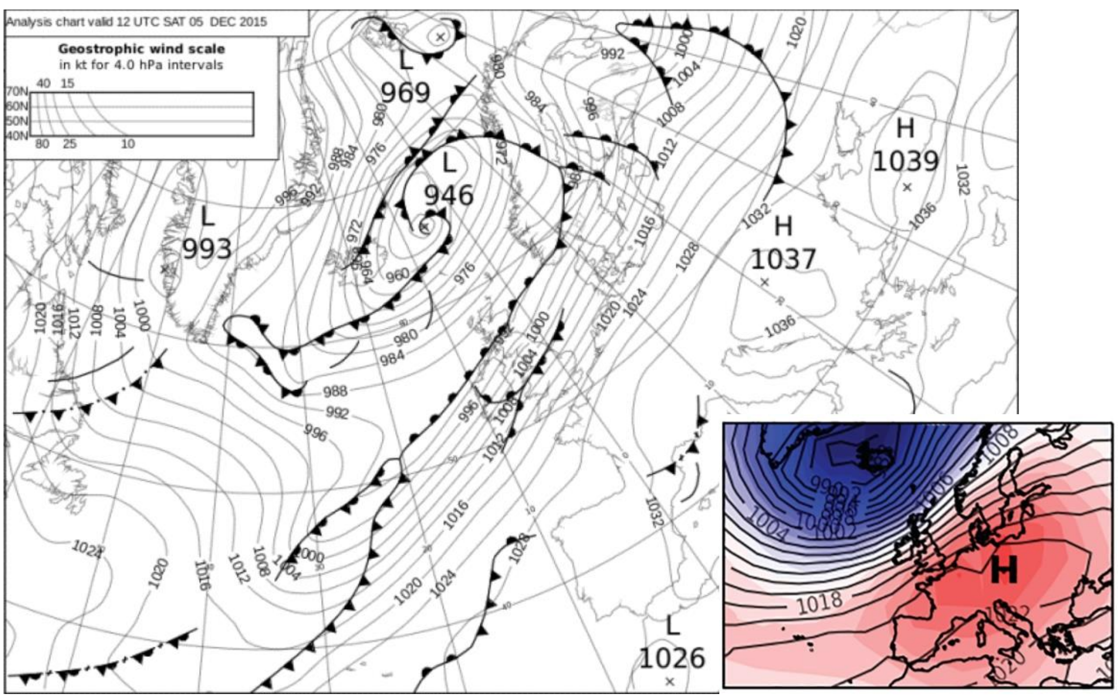
6. APPENDIX A – STORMS

6.1.1 Storm Desmond

Between the 4th and 6th December 2015, Storm Desmond led to exceptionally high rainfall across the north of England. Whilst extreme precipitation was widely reported across Cumbria (including a new rainfall record of 341.4mm at Honister Pass in 24-hours), heavy rainfall also affected the North-East and led to service disruptions. The resulting flooding and other storm damages led to minor incidents at many sites across the network.

The event was caused by a deep low-pressure system to the east of Iceland with fronts stretching across the north of Britain and a mild, moist south-westerly airstream forced to rise when reaching high ground, bringing prolonged and heavy rainfall across inland areas. As reported by the Met-Office, this mechanism, known as a 'warm conveyor' was very similar to the heavy rainfall and flooding that affected Cumbria in November 2009 as well as the January 2005 floods in Carlisle. The latter flood also washed away the river crossings to Hexham and surrounds leading to a no supply incident. Figure presents the atmospheric conditions during the event, which can be attributed to weather pattern 15, described as neutral south-westerly and very windy for northwest Britain. This weather pattern has a 3% frequency of occurrence in the historical record, mostly during winter.

FIGURE 19: STORM DESMOND SYNOPTIC MAP AND WEATHER PATTERN



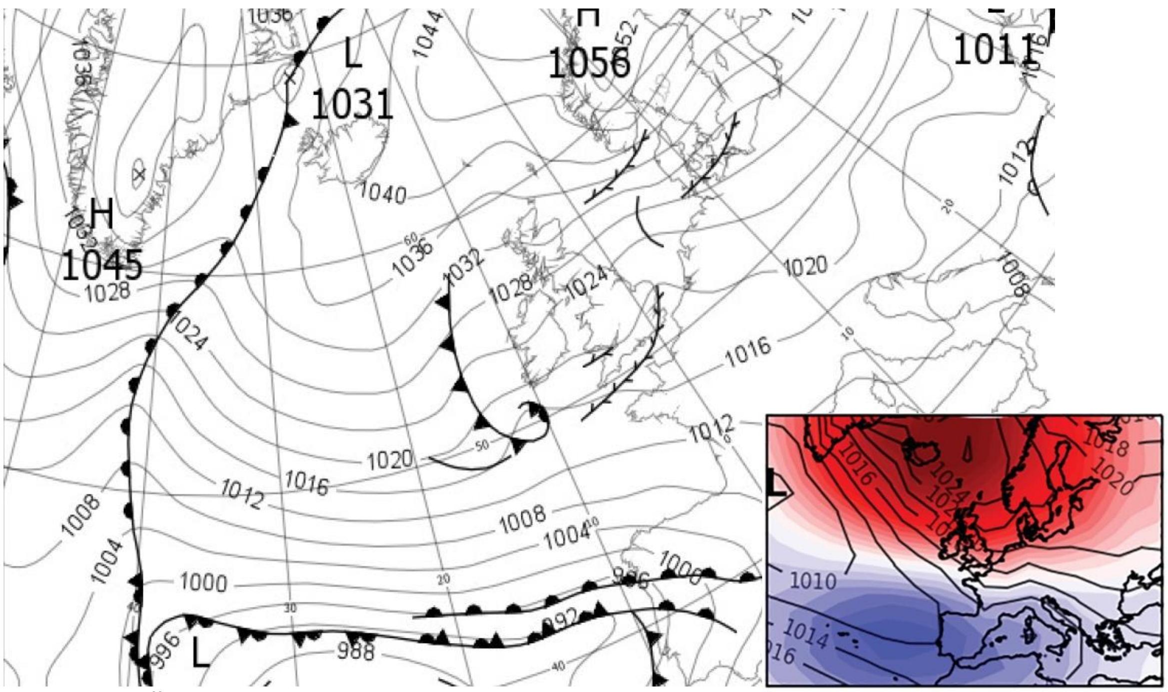
Source: Met Office

6.1.2 The Beast from the East

In late February and early March 2018, a spell of very low temperatures (below freezing levels) and significant snowfalls affected much of the country after a period of mild temperatures. Large areas of high pressure across Scandinavia and northern Europe combined with milder air within the Atlantic system led to an easterly airflow bringing cold air from Finland, north-west Russia, and the Barents Sea to the UK. The freezing temperatures combined with a strong east wind, particularly on 28 February and 1 March, resulted in a wind-chill at times widely below -10 °C. A rise in temperatures during the first half of March was followed by another spell of snow and low temperatures between the 17th and 19th March with temperatures still fluctuating around freezing levels across upland areas of northern England and parts of the south-east. During the event, areas of the South-East became the most exposed to the easterly airflow.

Figure presents the atmospheric conditions during the event, which can be attributed to weather pattern 27, described as Anticyclonic easterly with high pressure over the Norwegian Sea. This weather pattern has a 1.8% frequency of occurrence in the historical record, mostly in winter.

Figure 20: Beast from the East synoptic map and weather pattern



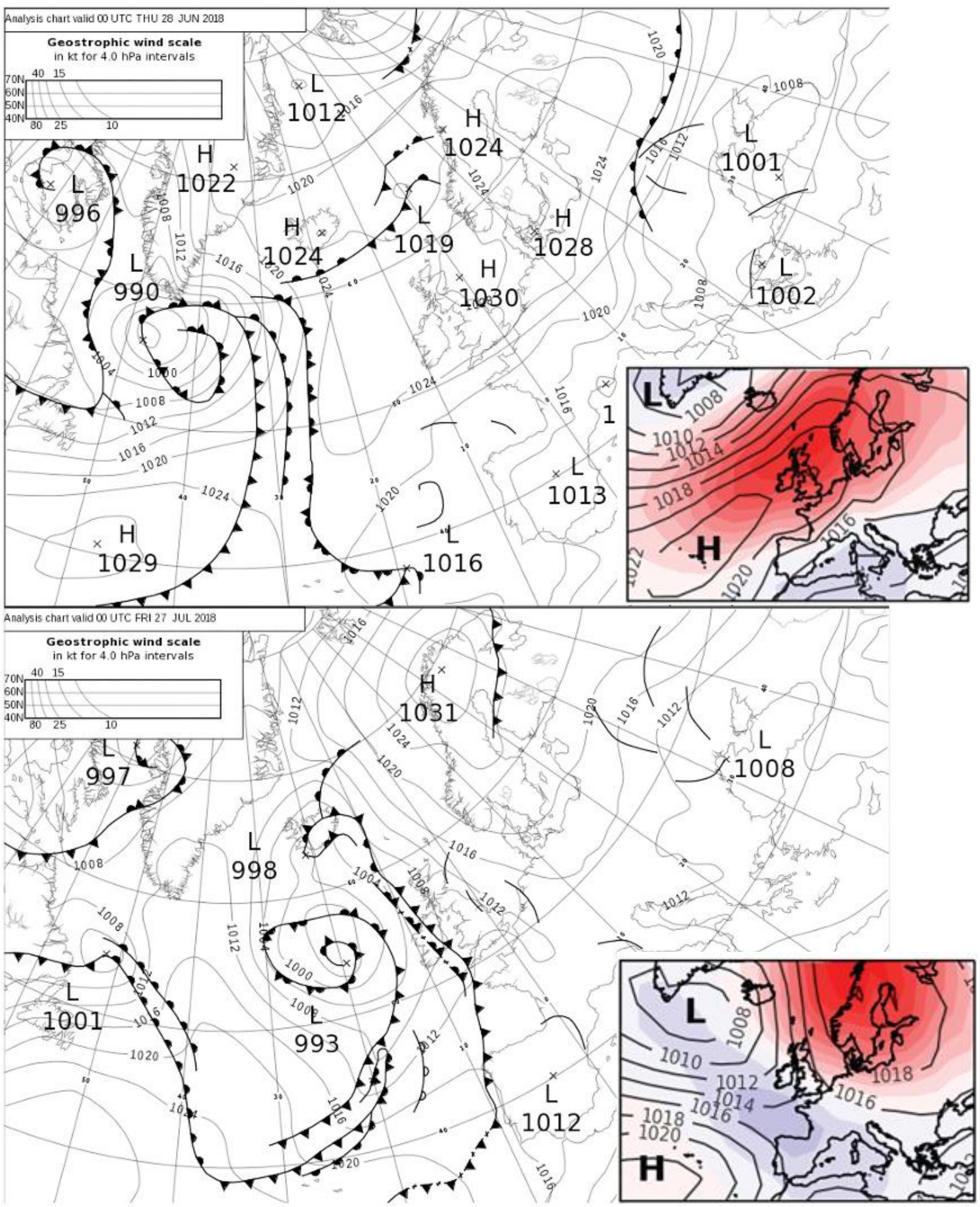
Source: Met Office

6.1.3 2018 Summer heat wave

Summer 2018 was the UK's warmest summer since 2006 and the driest since 2003, often influenced by high atmospheric pressures. The event was recorded as the fifth driest summer in a series from 1910 with the summers of 1995, 1976, 1983 and 1913 being drier. June was exceptionally dry across parts of southern England with records of over 50 dry days at some stations in the south-east lasting until late July.

Figure presents the predominant atmospheric conditions during that period, which can be attributed to weather patterns 5 and 6. On one hand pattern 5 is described as neutral southerly with a centre of high pressure over Scandinavia. On the other hand, pattern 6 is described as anticyclonic with a high-pressure centre over the Azores. Both have a 4.9% frequency of occurrence in the historical record, more concentrated in summer.

Figure 21: 2018 heat wave synoptic maps and weather patterns



Source: Met Office

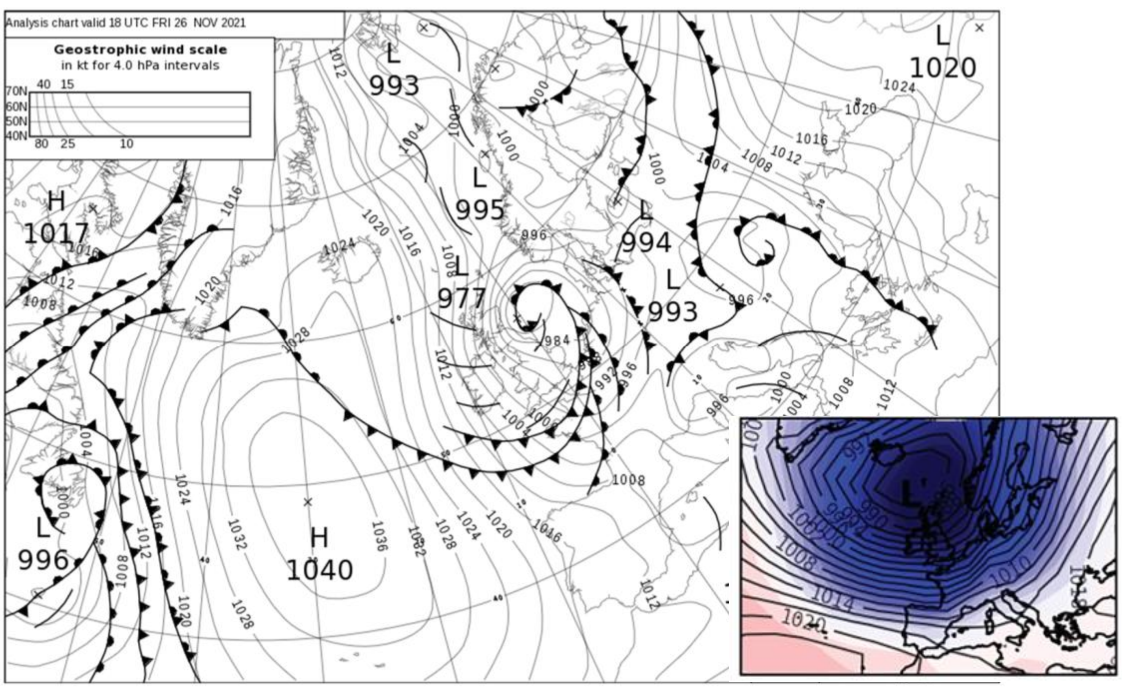
6.1.4 Storm Arwen

Between the 26th and 27th November 2021, extreme winds coming from the North Sea were recorded mainly across the north-east of England and eastern Scotland. Storm Arwen was reported by the Met Office as one of the most damaging windstorms of the latest decade with wind gusts reaching 50 to 60Kt (58 to 69mph) widely and exceeding 60Kt in many exposed coastal locations. The highest gust speed of 85Kt (98mph) was recorded at Brizlee Wood in Northumberland which remains exceptional for the north-east of England. The previous maximum record for the north-east was 89Kt (102mph) at Lynemouth, Northumberland, on 16 January 1984.

The northerly airflow associated with the storm also brought some very low temperatures and some significant snow accumulation, particularly across parts of the Pennines.

This event was classified as a civil emergency due to the nature of the disruption to power, access, and amenities. Figure presents the atmospheric conditions during the event, which can be attributed to weather pattern 30, described as cyclonic west-north-westerly with deep low pressure southeast of Iceland and very windy. This weather pattern has a 1.5% frequency of occurrence in the historical record, mostly in winter.

Figure 22: Storm Arwen synoptic map and weather pattern



Source: Met Office

6.1.5 Other heavy rainfall events

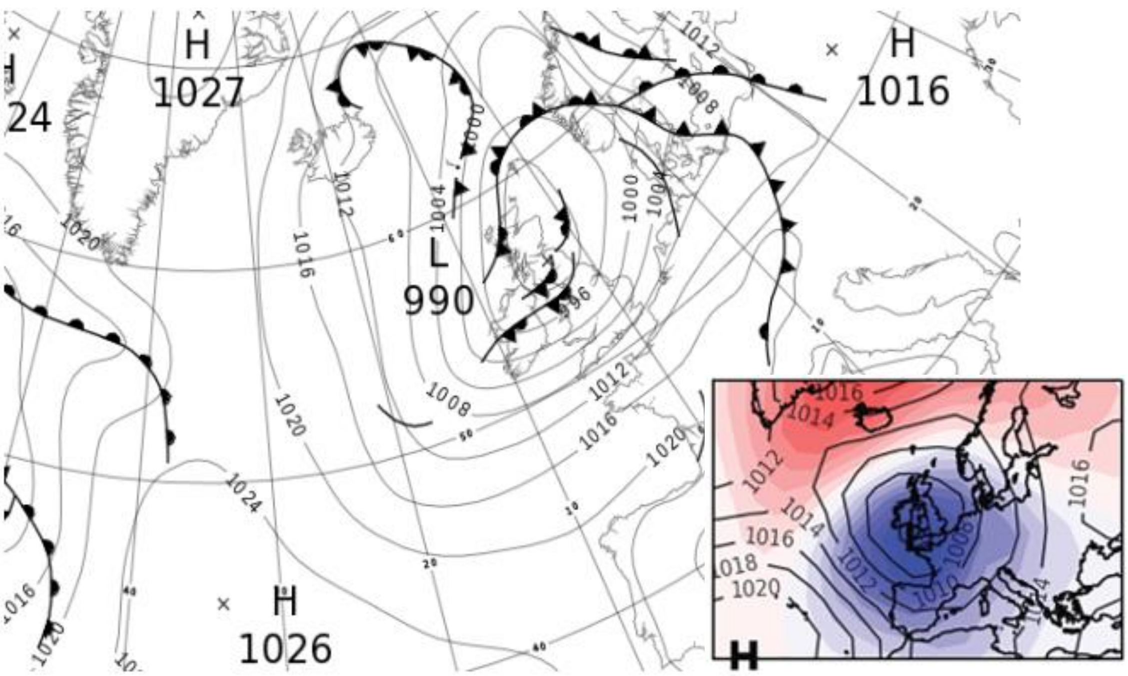
Ex-Hurricane Bertha

The remnants of Hurricane Bertha affected the North-East of Scotland as well as areas in the North-East of England between the 10th and 11th August 2014 with high wind and persistent extreme rainfall that led to flooding in various parts of the country, including in the North-East. This storm can be associated with weather pattern 24, described as cyclonic northerly with low pressure centred over the North Sea. This weather pattern has a 2% frequency of occurrence in the historical record, mostly in winter.

August 2019 storms

On the 10th of August 2019 northern England and southern Scotland were affected by heavy rain, turning thundery in places, and accompanied by strong winds. Figure presents the atmospheric conditions during the event, which can be better related to weather pattern 11, described as cyclonic with a low-pressure centre over southern Britain. This weather pattern has a 3.7% frequency of occurrence in the historical record, mostly in summer.

Figure 23: August 2019 storm synoptic map and weather pattern

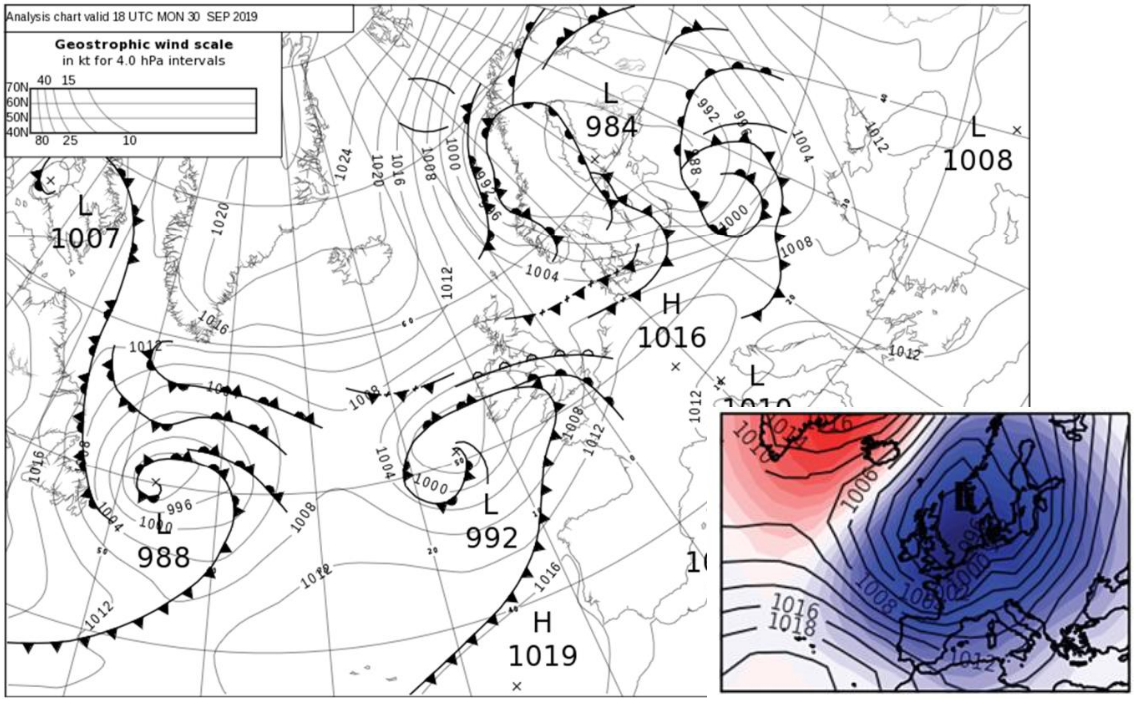


Wet weather spells and Storm Lorenzo

Storm Lorenzo, a mid-Atlantic hurricane, that passed across the UK between the 3rd and the 4th of October 2019 followed a period of wet weather conditions from late September and heavy rainfall on the 1st of October which led to flooding in parts of the country prior to the hurricane arriving. Heavy rain fell across northern England on the 30 September and thunderstorms brought torrential rain across southern England the following day.

Figure presents the atmospheric conditions during the event, which can be better attributed to weather pattern 24.

Figure 24: Storm Lorenzo synoptic map and weather pattern

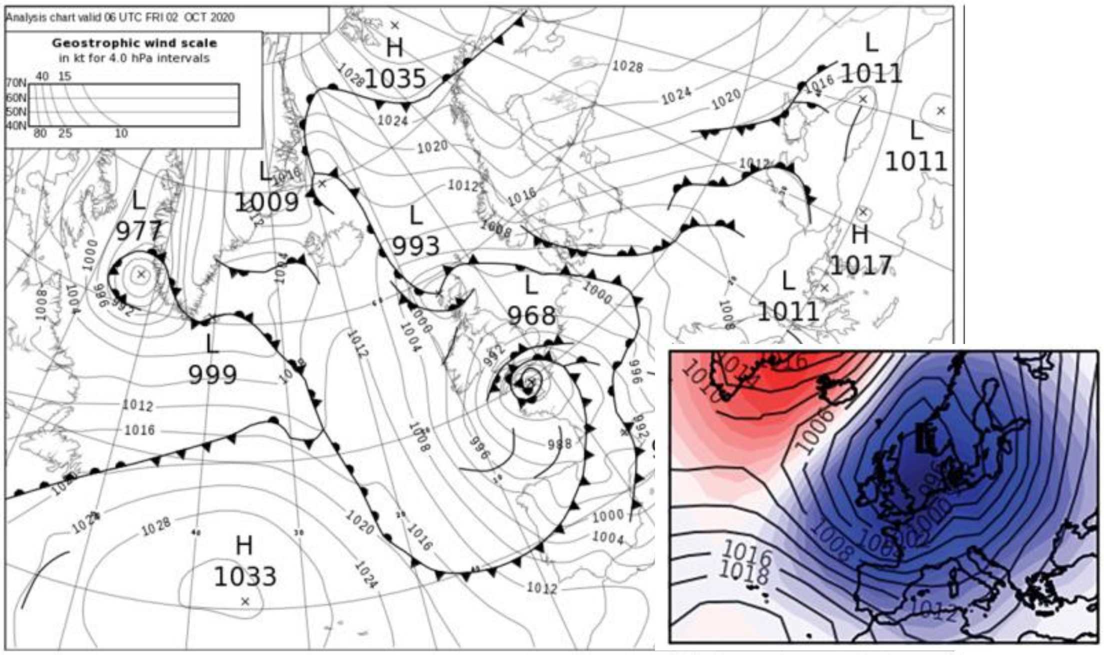


Storm Alex followed by heavy rainfall

Storm Alex brought strong winds to the southern half of the UK on the 2nd of October 2020 as well as heavy rain across southern England. A low-pressure system remained in place for a couple of days and associated fronts led to prolonged and widespread heavy rain in the following days (3rd and 4th), affecting much of the country. In the first four days of the month, 50 to 75mm or more of rain fell widely across southern England with areas recording totals of 100mm. The extensive nature of the rain resulted in the UK receiving 31.7mm as an area-average for the 3rd of October 2020, making it the wettest day on record in a daily series back to 1891.

Figure 25 presents the atmospheric conditions during the event, which can be better attributed to weather pattern 24.

Figure 25: Storm Alex synoptic map and weather pattern



Source: Met Office

7. APPENDIX B – LIST OF NEEDS

TABLE 36: LIST OF NEEDS FOR WASTEWATER SITES FOR AMP8

WASTEWATER SITE NAME	ASSET TYPE	FLOODING NEED	POWER NEED	SITE LOCATION CODE
Allendale	STW	Y		ALLEW1
Alnwick	STW	Y		ALNWW1
Amble Harbour	SPS		Y	AMHAP1
Amble	STW	Y	Y	AMBEW1
Atlas Wynd	SPS	Y		YAAWP1
Aycliffe	STW	Y		AYCLW1
Aycliffe Woodham Bridge	SPS	Y		WDBRP1
Ayton	STW	Y		AYTNW1
Barberry Close Ingleby Barwick	SPS		Y	BARBP1
Bardon Mill (Redburn) Indirect	SPS	Y		REBUP1
Bardon Mill	STW	Y		BARMW1
Barkers Haugh STW Inlet	SPS		Y	BAHAW1
Barnard Castle	STW	Y		BACAW1
Barton	STW		Y	BARTW1
Beadnell Sea Outfall	SPS	Y		BEHAP1
Belford	SPS	Y		BLFDP1
Bellingham	STW	Y		BELLW1
Belmont	STW	Y		BELMW1
Berwick No 3 Bridge Street	SPS		Y	BESBP1
Berwick Upon Tweed	STW	Y		BERWW1
Billingham	STW	Y	Y	BLLGW1
Billingham STW Terminal	SPS		Y	BLLGW1
Birtley (Gateshead)	STW	Y		BRTLW1
Blackhall Mill	SPS	Y		BLMLP1
Blyth	STW	Y	Y	BLYTW1
Bowburn	STW		Y	BWBUW1
Bran Sands	STW		Y	BRANW1
Brasside	SPS	Y		BRASP1
Bridge Street	SPS	Y		HBSHP1
Brierdene Storm	SPS		Y	BRBBP1
Browns Point A44	SPS	Y		CUCRP1
Brus Hartlepool	SPS		Y	HPBRP1
Butterknowle	STW	Y		BUTTW1
Cambois	STW	Y		CMBSW1
Cambois STW North Seaton Terminal	SPS		Y	CMBSW1
Castletown Way	SPS		Y	CAWAP1
Chester Le Street	STW		Y	CLSSW1
Cheveley Park	SPS	Y		BRGAP1
Cleasewell Hill	SPS		Y	SHEEP1

WASTEWATER SITE NAME	ASSET TYPE	FLOODING NEED	POWER NEED	SITE LOCATION CODE
Cockfield	STW	Y		CLFSW1
Coniscliffe Road	SPS	Y		BSPAP1
Corbridge	SPS	Y		DLSTP1
Cottage Road Wooler	SPS		Y	CTRWP1
Cramlington	STW	Y		CRAMW1
Crimdon Dene	SPS	Y		CRPCP1
Crookhall	STW	Y		CRKMW1
Dene Holme	SPS		Y	DHHDP1
Dene Park	SPS		Y	DPPLP1
Dilston Haugh	SPS		Y	DLSTP1
East Castle North	STW		Y	ETCNW1
East Castle South	STW		Y	EACSW1
East Hartford	SPS		Y	EAHAP1
East Of Auction Mart	SPS		Y	EAMAP1
East Sleekburn	SPS	Y		EASLP1
East Tanfield	SPS	Y	Y	APSEP1
Eglingham	SPS		Y	EGHMP1
Elemore Vale	SPS	Y		HLHVP1
Embleton	STW	Y		EMBLW1
Fatfield	SPS	Y		FATRP1
Felton	SPS	Y		FELTP1
Ferryhill North	SPS	Y		FNDRP1
Friarside Crescent	STW		Y	FRARW1
Friary Farm Bamburgh	SPS		Y	BAFFP1
Gainford	STW	Y		GANFW1
Gordon Terrace Ferryhill	SPS	Y	Y	GRDTP1
Great Broughton	SPS	Y		GBHSP1
Hadston	SPS		Y	HADSP1
Haltwhistle	STW	Y		HALTW1
Haverton Hill	SPS	Y		FURNP1
Hebburn (Marine Drive)	SPS	Y		MDHBP1
Hendon	STW	Y	Y	HNDNW1
Hendon STW Inlet	SPS		Y	HNDNW1
Hexham	STW		Y	HEXHW1
High Coniscliffe	SPS	Y		HGCNP1
Horden	STW	Y		EAHSW1
Howdon Secondary	STW	Y	Y	HWDNW1
Howdon Secondary SPS	SPS	Y		WQTTP1
Hummersnot	SPS	Y		HUMKP1
Hurworth Place	SPS	Y	Y	HURPP1
Hustledown	STW	Y		HSDNW1

WASTEWATER SITE NAME	ASSET TYPE	FLOODING NEED	POWER NEED	SITE LOCATION CODE
Hutton Rudby	STW	Y		HUTRW1
Hutton Rudby	SPS	Y		NGBRP2
Knitsley	STW	Y		KGFDW1
Lanchester	STW	Y	Y	LANCW1
Land At Cargo Fleet Middlesbrough	SPS	Y		MELSP2
Leamside	STW	Y		LEAMW1
Leasingthorne	SPS		Y	LEATP1
Levenside No.2	SPS	Y		LEVSP2
Leyland Bridge	SPS		Y	LEYBP1
Low Coniscliffe	SPS	Y		LWCNP1
Low Wadsworth	STW	Y	Y	LWWAW1
Lustrum	SPS		Y	LUSTP1
Lynemouth	STW	Y		LVSVW1
Mainsforth Terrace	SPS		Y	HBRBP1
Marden Quarry	SPS		Y	MARDP1
Marske	STW		Y	MARSW1
Melsonby	STW	Y		MELYW1
Middleton One Row	SPS	Y		MDRWP1
Middleton-In-Teesdale	STW	Y		MNTMW1
Milk Market	SPS	Y	Y	NCBCP1
Morpeth	STW	Y		MRPTW1
Morton Park	SPS		Y	MRTPP1
New Moors	STW	Y		NEWMW1
Newbiggin By The Sea	STW	Y		NEWBW1
Newburn	SPS		Y	NEBUP1
Newton Aycliffe Monks End	SPS		Y	NAMEP1
Newton Hall No.1 (Salisbury R)	SPS	Y		SALBP1
Newton Hall No.2 (Lindisfarne)	SPS	Y		LNDSP1
North Tees	SPS	Y	Y	NRTEP1
Old River Tees	SPS		Y	TSDPP2
Pattinson South	SPS	Y	Y	PATTP2
Patton Way Pegswood	SPS	Y		PAWAP1
Pear Tree	STW		Y	PEARW1
Pegswood	STW	Y		PEGSW1
Pittington	STW	Y		PCVDW1
PLAWSWORTH (Due To Be SPS On Transfer)	STW	Y		NPGAW1
Pont No.1	SPS		Y	BCPLP1
Pont No.2	SPS		Y	BCPLP2
Portrack	SPS	Y		PTRAP1
Potto	SPS	Y		PTTTP1
Ramshaw	SPS	Y		RAMSP1

WASTEWATER SITE NAME	ASSET TYPE	FLOODING NEED	POWER NEED	SITE LOCATION CODE
Red Row	SPS	Y		REDBP1
Redcar Zetland	SPS		Y	REZEP1
Rennington	SPS	Y		RENNP1
Roker Gill	SPS	Y	Y	RKEGP1
Rothbury Aln D C	SPS	Y	Y	RTHBP1
Rowlands Gill Lochaugh	STW	Y		LCKHW1
Saltburn	SPS		Y	SBANP1
Saltmeadows	SPS		Y	SAARP1
Scotswood Road No.2	SPS		Y	BSRSP1
Seaburn Promenade	SPS		Y	SEABP2
Seaburn	SPS		Y	SEABP1
Seaham Hall (Byrons Walk)	SPS	Y		NRTHP2
Seaham	STW	Y		SEAHW1
Seaham STW Inlet	SPS		Y	SEAHW1
Seaham(Northlea)	SPS	Y		NRTHP1
Seahouses	STW		Y	SEHUW1
Seaton Carew (Brenda Road)	STW		Y	BRRDW1
Seaton Sluice	SPS		Y	SEATP1
Seaton Sluice Storages Tank	SPS	Y		SEATP1
Sedgeletch	STW	Y	Y	HHSTW1
Sedgeletch STW Inlet	SPS		Y	HHSTW1
Seghill No 1 (Deneside) - Indirect	SPS	Y		SEGHP1
Shilbottle	STW	Y		SHLBW1
Skinningrove	SPS		Y	MARSP1
Snowdon Road	SPS	Y	Y	SNWRP1
South Hylton	STW		Y	NRHYW1
St Peters	SPS		Y	STPEP1
Staindrop	STW	Y		SUSTW1
Startforth	SPS	Y		STDEP1
Stokesley Levenside	SPS	Y		LEVSP1
Stokesley	STW	Y		STKEW1
Stonebridge	SPS	Y		DUSTP1
Sunderland Bridge	STW	Y		SBLDW1
Sunnybrow Pump.Stat.	SPS	Y		SUNNP1
Swainby	STW	Y	Y	SWANW1
Swarland Fence	SPS	Y	Y	SWFEP1
Teesside Airport	STW	Y		GBECW1
The Lee, Rothbury (Embleton Ter.)	STW		Y	TLEEW1
The Old Forge Ladgate Lane	SPS		Y	LFLLP1
The Tannery	SPS	Y		ASLAP1
Thorpe Street Hartlepool	SPS		Y	THSHP1

WASTEWATER SITE NAME	ASSET TYPE	FLOODING NEED	POWER NEED	SITE LOCATION CODE
Throstles Nest	SPS		Y	THNEP1
Togston	STW	Y		TGSTW1
Tursdale	SPS	Y		TURSP1
University	STW		Y	UNVEW1
Warkworth No 3 (The Butts)-Aln D	SPS	Y		WWBTP1
Washington	STW	Y		WSHNW1
West Cornforth	SPS	Y	Y	WCUFP1
Whitburn Steel	SPS		Y	WHPAP1
Willow Green	STW	Y		FRSTW1
Witton Gilbert	STW	Y		WTTGW1
Woodham Bridge	SPS		Y	WDBRP1
Worsall Road	SPS	Y		WRSSP1

TABLE 37: LIST OF NEEDS FOR WATER SITES FOR AMP8

Site	Region	Flooding 1 in 100 yr	Power
Barsham WTW	E&S	Yes	No
Bay Bridge WPS	NWL	Yes	No
Benhall WTW	NWL	Yes	No
Bleach Green WPS	E&S	No	Yes
Coldfair Green WTW	E&S	Yes	No
Coxhoe (Cornforth Lane) WPS	NWL	Yes	No
Langford WTW	E&S	No	Yes
Matfen WPS	NWL	Yes	No
Murton WTW (Thornton Main Bore)	NWL	No	Yes
Ormesby WTW	E&S	No	Yes
Stifford WTW	E&S	Yes	No
Warkworth WTW	NWL	No	Yes
Wortham Bore	E&S	No	Yes
		7	6

8. APPENDIX C – COST BENEFIT RATIOS AND PREFERRED OPTION

TABLE 38: NET PRESENT VALUES AND SELECTED OPTIONS FOR WASTEWATER POWER

Site Name	Option	Value NPV £M	Least Cost	Chosen Option
Amble Harbour WWP	Fixed Standby Generator	1.120	N	Preferred option
Amble Harbour WWP	Plug in Socket	0.434	N	Alternative option
Amble Harbour WWP	Portable Generator	0.086	N	Alternative option
Amble Harbour WWP	Upsized UPS	0.163	Y	Alternative option
Amble STW	Fixed Standby Generator	1.382	N	Preferred option
Amble STW	Plug in Socket	0.434	N	Alternative option
Amble STW	Portable Generator	0.434	N	Alternative option
Amble STW	Upsized UPS	0.166	Y	Alternative option
Barberry Close Ingleby Barwick WWP	Fixed Standby Generator	1.236	N	Preferred option
Barberry Close Ingleby Barwick WWP	Plug in Socket	0.442	N	Alternative option
Barberry Close Ingleby Barwick WWP	Portable Generator	0.114	N	Alternative option
Barberry Close Ingleby Barwick WWP	Upsized UPS	0.150	Y	Alternative option
Barkers Haugh STW Inlet WWP	Fixed Standby Generator	0.952	N	Preferred option
Barkers Haugh STW Inlet WWP	Plug in Socket	0.384	N	Alternative option
Barkers Haugh STW Inlet WWP	Portable Generator	0.002	N	Alternative option
Barkers Haugh STW Inlet WWP	Upsized UPS	0.146	Y	Alternative option
Barton STW	Fixed Standby Generator	1.490	N	Preferred option
Barton STW	Plug in Socket	0.435	N	Alternative option
Barton STW	Portable Generator	0.434	N	Alternative option
Barton STW	Upsized UPS	0.170	Y	Alternative option
Berwick No 3 Bridge Street WWP	Fixed Standby Generator	8.886	N	Preferred option
Berwick No 3 Bridge Street WWP	Plug in Socket	2.213	N	Alternative option
Berwick No 3 Bridge Street WWP	Portable Generator	3.554	N	Alternative option
Berwick No 3 Bridge Street WWP	Upsized UPS	0.235	Y	Alternative option
Billingham STW	Fixed Standby Generator	1.382	N	Preferred option
Billingham STW	Plug in Socket	0.434	N	Alternative option
Billingham STW	Portable Generator	0.434	N	Alternative option
Billingham STW	Upsized UPS	0.166	Y	Alternative option
Billingham STW - UV	Fixed Standby Generator	1.268	Y	Preferred option
Billingham STW Terminal WWP	Fixed Standby Generator	0.904	N	Preferred option
Billingham STW Terminal WWP	Plug in Socket	0.383	N	Alternative option
Billingham STW Terminal WWP	Portable Generator	0.002	N	Alternative option
Billingham STW Terminal WWP	Upsized UPS	0.143	Y	Alternative option
Blyth STW	Fixed Standby Generator	1.320	N	Preferred option
Blyth STW	Plug in Socket	0.433	N	Alternative option
Blyth STW	Portable Generator	0.434	N	Alternative option
Blyth STW	Upsized UPS	0.164	Y	Alternative option

Site Name	Option	Value NPV £M	Least Cost	Chosen Option
Bowburn STW	Fixed Standby Generator	1.373	N	Preferred option
Bowburn STW	Plug in Socket	0.433	N	Alternative option
Bowburn STW	Portable Generator	0.434	N	Alternative option
Bowburn STW	Upsized UPS	0.166	Y	Alternative option
Bran Sands STW - UV	Fixed Standby Generator	-0.426	N	Preferred option
Brierdene Storm WWP	Fixed Standby Generator	0.353	N	Preferred option
Brierdene Storm WWP	Plug in Socket	0.438	N	Alternative option
Brierdene Storm WWP	Portable Generator	-0.654	N	Alternative option
Brierdene Storm WWP	Upsized UPS	0.162	Y	Alternative option
Brus Hartlepool WWP	Fixed Standby Generator	1.324	N	Preferred option
Brus Hartlepool WWP	Plug in Socket	0.485	N	Alternative option
Brus Hartlepool WWP	Portable Generator	0.170	N	Alternative option
Brus Hartlepool WWP	Upsized UPS	0.181	Y	Alternative option
Cambois STW North Seaton Terminal WWP	Fixed Standby Generator	0.993	N	Preferred option
Cambois STW North Seaton Terminal WWP	Plug in Socket	0.391	N	Alternative option
Cambois STW North Seaton Terminal WWP	Portable Generator	0.002	N	Alternative option
Cambois STW North Seaton Terminal WWP	Upsized UPS	0.148	Y	Alternative option
Castletown Way WWP	Fixed Standby Generator	1.699	N	Preferred option
Castletown Way WWP	Plug in Socket	0.555	N	Alternative option
Castletown Way WWP	Portable Generator	0.336	N	Alternative option
Castletown Way WWP	Upsized UPS	0.153	Y	Alternative option
Chester Le Street STW	Fixed Standby Generator	1.521	N	Preferred option
Chester Le Street STW	Plug in Socket	0.442	N	Alternative option
Chester Le Street STW	Portable Generator	0.988	N	Alternative option
Chester Le Street STW	Upsized UPS	0.172	Y	Alternative option
Cleasewell Hill WWP	Fixed Standby Generator	1.055	N	Preferred option
Cleasewell Hill WWP	Plug in Socket	0.405	N	Alternative option
Cleasewell Hill WWP	Portable Generator	0.036	N	Alternative option
Cleasewell Hill WWP	Upsized UPS	0.155	Y	Alternative option
Cottage Road Wooler WWP	Fixed Standby Generator	1.538	N	Preferred option
Cottage Road Wooler WWP	Plug in Socket	0.445	N	Alternative option
Cottage Road Wooler WWP	Portable Generator	0.619	N	Alternative option
Cottage Road Wooler WWP	Upsized UPS	0.153	Y	Alternative option
Dene Holme WWP	Fixed Standby Generator	0.851	N	Preferred option
Dene Holme WWP	Plug in Socket	0.392	N	Alternative option
Dene Holme WWP	Portable Generator	0.019	N	Alternative option
Dene Holme WWP	Upsized UPS	0.143	Y	Alternative option

Site Name	Option	Value NPV £M	Least Cost	Chosen Option
Dene Park WWP	Fixed Standby Generator	1.039	N	Preferred option
Dene Park WWP	Plug in Socket	0.404	N	Alternative option
Dene Park WWP	Portable Generator	0.036	N	Alternative option
Dene Park WWP	Upsized UPS	0.153	Y	Alternative option
Dilston Haugh WWP	Fixed Standby Generator	1.203	N	Preferred option
Dilston Haugh WWP	Plug in Socket	0.441	N	Alternative option
Dilston Haugh WWP	Portable Generator	0.114	N	Alternative option
Dilston Haugh WWP	Upsized UPS	0.149	Y	Alternative option
East Castle North St	Fixed Standby Generator	1.611	N	Preferred option
East Castle North St	Plug in Socket	0.485	N	Alternative option
East Castle North St	Portable Generator	1.034	N	Alternative option
East Castle North St	Upsized UPS	0.174	Y	Alternative option
East Castle South STW	Fixed Standby Generator	1.611	N	Preferred option
East Castle South STW	Plug in Socket	0.485	N	Alternative option
East Castle South STW	Portable Generator	1.034	N	Alternative option
East Castle South STW	Upsized UPS	0.174	Y	Alternative option
East Hartford WWP	Fixed Standby Generator	0.947	N	Preferred option
East Hartford WWP	Plug in Socket	0.394	N	Alternative option
East Hartford WWP	Portable Generator	0.019	N	Alternative option
East Hartford WWP	Upsized UPS	0.147	Y	Alternative option
East Of Auction Mart WWP	Fixed Standby Generator	0.995	N	Preferred option
East Of Auction Mart WWP	Plug in Socket	0.391	N	Alternative option
East Of Auction Mart WWP	Portable Generator	0.002	N	Alternative option
East Of Auction Mart WWP	Upsized UPS	0.148	Y	Alternative option
East Tanfield WWP	Fixed Standby Generator	1.167	N	Preferred option
East Tanfield WWP	Plug in Socket	0.470	N	Alternative option
East Tanfield WWP	Portable Generator	0.164	N	Alternative option
East Tanfield WWP	Upsized UPS	0.152	Y	Alternative option
Eglingham WWP	Fixed Standby Generator	1.541	N	Preferred option
Eglingham WWP	Plug in Socket	0.445	N	Alternative option
Eglingham WWP	Portable Generator	0.619	N	Alternative option
Eglingham WWP	Upsized UPS	0.153	Y	Alternative option
Friarside Crescent STW	Fixed Standby Generator	1.611	N	Preferred option
Friarside Crescent STW	Plug in Socket	0.485	N	Alternative option
Friarside Crescent STW	Portable Generator	1.034	N	Alternative option
Friarside Crescent STW	Upsized UPS	0.174	Y	Alternative option
Friary Farm Bamburgh WWP	Fixed Standby Generator	1.505	N	Preferred option
Friary Farm Bamburgh WWP	Plug in Socket	0.434	N	Alternative option
Friary Farm Bamburgh WWP	Portable Generator	0.603	N	Alternative option

Site Name	Option	Value NPV £M	Least Cost	Chosen Option
Friary Farm Bamburgh WWP	Upsized UPS	0.150	Y	Alternative option
Gordon Terrace WWP	Fixed Standby Generator	0.988	N	Preferred option
Gordon Terrace WWP	Plug in Socket	0.385	N	Alternative option
Gordon Terrace WWP	Portable Generator	0.002	N	Alternative option
Gordon Terrace WWP	Upsized UPS	0.148	Y	Alternative option
Hadston WWP	Fixed Standby Generator	0.964	N	Preferred option
Hadston WWP	Plug in Socket	0.384	N	Alternative option
Hadston WWP	Portable Generator	0.002	N	Alternative option
Hadston WWP	Upsized UPS	0.146	Y	Alternative option
Hendon STW	Fixed Standby Generator	1.504	N	Preferred option
Hendon STW	Plug in Socket	0.457	N	Alternative option
Hendon STW	Portable Generator	0.487	N	Alternative option
Hendon STW	Upsized UPS	0.175	Y	Alternative option
Hendon STW - UV	Fixed Standby Generator	0.741	Y	Preferred option
Hendon STW Inlet WWP	Fixed Standby Generator	0.827	N	Preferred option
Hendon STW Inlet WWP	Plug in Socket	0.382	N	Alternative option
Hendon STW Inlet WWP	Portable Generator	0.002	N	Alternative option
Hendon STW Inlet WWP	Upsized UPS	0.140	Y	Alternative option
Hexham STW	Fixed Standby Generator	1.506	N	Preferred option
Hexham STW	Plug in Socket	0.435	N	Alternative option
Hexham STW	Portable Generator	0.434	N	Alternative option
Hexham STW	Upsized UPS	0.172	Y	Alternative option
Howdon STW - UV	Fixed Standby Generator	-0.792	N	Preferred option
Hurworth Place WWP	Fixed Standby Generator	1.277	N	Preferred option
Hurworth Place WWP	Plug in Socket	0.458	N	Alternative option
Hurworth Place WWP	Portable Generator	0.130	N	Alternative option
Hurworth Place WWP	Upsized UPS	0.154	Y	Alternative option
Lanchester STW	Fixed Standby Generator	1.490	N	Preferred option
Lanchester STW	Plug in Socket	0.435	N	Alternative option
Lanchester STW	Portable Generator	0.434	N	Alternative option
Lanchester STW	Upsized UPS	0.170	Y	Alternative option
Leasingthorne WWP	Fixed Standby Generator	0.988	N	Preferred option
Leasingthorne WWP	Plug in Socket	0.385	N	Alternative option
Leasingthorne WWP	Portable Generator	0.002	N	Alternative option
Leasingthorne WWP	Upsized UPS	0.148	Y	Alternative option
Leyland Bridge WWP	Fixed Standby Generator	1.235	N	Preferred option
Leyland Bridge WWP	Plug in Socket	0.451	N	Alternative option
Leyland Bridge WWP	Portable Generator	0.130	N	Alternative option
Leyland Bridge WWP	Upsized UPS	0.152	Y	Alternative option

Site Name	Option	Value NPV £M	Least Cost	Chosen Option
Low Wadsworth STW	Fixed Standby Generator	1.523	N	Preferred option
Low Wadsworth STW	Plug in Socket	0.457	N	Alternative option
Low Wadsworth STW	Portable Generator	0.487	N	Alternative option
Low Wadsworth STW	Upsized UPS	0.176	Y	Alternative option
Lustrum WWP	Fixed Standby Generator	0.298	N	Preferred option
Lustrum WWP	Plug in Socket	0.391	N	Alternative option
Lustrum WWP	Portable Generator	0.013	N	Alternative option
Lustrum WWP	Upsized UPS	0.140	Y	Alternative option
Mainsforth Terrace WWP	Fixed Standby Generator	0.332	N	Preferred option
Mainsforth Terrace WWP	Plug in Socket	0.401	N	Alternative option
Mainsforth Terrace WWP	Portable Generator	0.030	N	Alternative option
Mainsforth Terrace WWP	Upsized UPS	0.144	Y	Alternative option
Marden Quarry WWP	Fixed Standby Generator	0.328	N	Preferred option
Marden Quarry WWP	Plug in Socket	0.395	N	Alternative option
Marden Quarry WWP	Portable Generator	-0.757	N	Alternative option
Marden Quarry WWP	Upsized UPS	0.147	Y	Alternative option
Marske STW	Fixed Standby Generator	0.420	N	Preferred option
Marske STW	Plug in Socket	0.437	N	Alternative option
Marske STW	Portable Generator	-0.316	N	Alternative option
Marske STW	Upsized UPS	0.161	Y	Alternative option
Marske STW - UV	Fixed Standby Generator	0.899	N	Preferred option
Milk Market WWP	Fixed Standby Generator	1.812	N	Preferred option
Milk Market WWP	Plug in Socket	0.605	N	Alternative option
Milk Market WWP	Portable Generator	0.420	N	Alternative option
Milk Market WWP	Upsized UPS	0.167	Y	Alternative option
Morton Park WWP	Fixed Standby Generator	1.212	N	Preferred option
Morton Park WWP	Plug in Socket	0.441	N	Alternative option
Morton Park WWP	Portable Generator	0.114	N	Alternative option
Morton Park WWP	Upsized UPS	0.149	Y	Alternative option
Newburn WWP	Fixed Standby Generator	0.981	N	Preferred option
Newburn WWP	Plug in Socket	0.404	N	Alternative option
Newburn WWP	Portable Generator	0.036	N	Alternative option
Newburn WWP	Upsized UPS	0.150	Y	Alternative option
Newton Aycliffe Monks End WWP	Fixed Standby Generator	1.605	N	Preferred option
Newton Aycliffe Monks End WWP	Plug in Socket	0.465	N	Alternative option
Newton Aycliffe Monks End WWP	Portable Generator	0.653	N	Alternative option
Newton Aycliffe Monks End WWP	Upsized UPS	0.160	Y	Alternative option
North Tees WWP	Fixed Standby Generator	1.292	N	Preferred option
North Tees WWP	Plug in Socket	0.462	N	Alternative option

Site Name	Option	Value NPV £M	Least Cost	Chosen Option
North Tees WWP	Portable Generator	0.147	N	Alternative option
North Tees WWP	Upsized UPS	0.155	Y	Alternative option
Old River Tees WWP	Fixed Standby Generator	0.970	N	Preferred option
Old River Tees WWP	Plug in Socket	0.619	N	Alternative option
Old River Tees WWP	Portable Generator	-0.382	N	Alternative option
Old River Tees WWP	Upsized UPS	0.219	Y	Alternative option
Pattinson South WWP	Fixed Standby Generator	1.552	N	Preferred option
Pattinson South WWP	Plug in Socket	0.519	N	Alternative option
Pattinson South WWP	Portable Generator	0.259	N	Alternative option
Pattinson South WWP	Upsized UPS	0.159	Y	Alternative option
Pear Tree	Fixed Standby Generator	1.611	N	Preferred option
Pear Tree	Plug in Socket	0.485	N	Alternative option
Pear Tree	Portable Generator	1.034	N	Alternative option
Pear Tree	Upsized UPS	0.174	Y	Alternative option
Pont No1 WWP	Fixed Standby Generator	0.873	N	Preferred option
Pont No1 WWP	Plug in Socket	0.393	N	Alternative option
Pont No1 WWP	Portable Generator	0.019	N	Alternative option
Pont No1 WWP	Upsized UPS	0.144	Y	Alternative option
Pont No2 WWP	Fixed Standby Generator	0.949	N	Preferred option
Pont No2 WWP	Plug in Socket	0.384	N	Alternative option
Pont No2 WWP	Portable Generator	0.002	N	Alternative option
Pont No2 WWP	Upsized UPS	0.146	Y	Alternative option
Redcar Zetland WWP	Fixed Standby Generator	1.205	N	Preferred option
Redcar Zetland WWP	Plug in Socket	0.846	N	Alternative option
Redcar Zetland WWP	Portable Generator	0.027	N	Alternative option
Redcar Zetland WWP	Upsized UPS	0.297	Y	Alternative option
Roker Gill WWP	Fixed Standby Generator	1.254	N	Preferred option
Roker Gill WWP	Plug in Socket	0.451	N	Alternative option
Roker Gill WWP	Portable Generator	0.130	N	Alternative option
Roker Gill WWP	Upsized UPS	0.152	Y	Alternative option
Rothbury Aln D C WWP	Fixed Standby Generator	1.230	N	Preferred option
Rothbury Aln D C WWP	Plug in Socket	0.442	N	Alternative option
Rothbury Aln D C WWP	Portable Generator	0.114	N	Alternative option
Rothbury Aln D C WWP	Upsized UPS	0.150	Y	Alternative option
Saltburn WWP	Fixed Standby Generator	0.245	N	Preferred option
Saltburn WWP	Plug in Socket	0.384	N	Alternative option
Saltburn WWP	Portable Generator	-0.774	N	Alternative option
Saltburn WWP	Upsized UPS	0.144	Y	Alternative option
Saltmeadows WWP	Fixed Standby Generator	1.024	N	Preferred option

Site Name	Option	Value NPV £M	Least Cost	Chosen Option
Saltmeadows WWP	Plug in Socket	0.414	N	Alternative option
Saltmeadows WWP	Portable Generator	0.053	N	Alternative option
Saltmeadows WWP	Upsized UPS	0.155	Y	Alternative option
Scotswood Road No2 WWP	Fixed Standby Generator	0.996	N	Preferred option
Scotswood Road No2 WWP	Plug in Socket	0.394	N	Alternative option
Scotswood Road No2 WWP	Portable Generator	0.019	N	Alternative option
Scotswood Road No2 WWP	Upsized UPS	0.150	Y	Alternative option
Seaburn Promenade WWP	Fixed Standby Generator	1.506	N	Preferred option
Seaburn Promenade WWP	Plug in Socket	0.434	N	Alternative option
Seaburn Promenade WWP	Portable Generator	0.603	N	Alternative option
Seaburn Promenade WWP	Upsized UPS	0.150	Y	Alternative option
Seaburn WWP	Fixed Standby Generator	5.981	N	Preferred option
Seaburn WWP	Plug in Socket	1.578	N	Alternative option
Seaburn WWP	Portable Generator	2.302	N	Alternative option
Seaburn WWP	Upsized UPS	0.222	Y	Alternative option
Seaham STW Inlet WWP	Fixed Standby Generator	0.913	N	Preferred option
Seaham STW Inlet WWP	Plug in Socket	0.384	N	Alternative option
Seaham STW Inlet WWP	Portable Generator	0.002	N	Alternative option
Seaham STW Inlet WWP	Upsized UPS	0.143	Y	Alternative option
Seahouses STW	Fixed Standby Generator	0.486	N	Preferred option
Seahouses STW	Plug in Socket	0.432	N	Alternative option
Seahouses STW	Portable Generator	0.434	N	Alternative option
Seahouses STW	Upsized UPS	0.163	Y	Alternative option
Seaton Carew STW - UV	Fixed Standby Generator	0.862	Y	Preferred option
Seaton Sluice WWP	Fixed Standby Generator	0.898	N	Preferred option
Seaton Sluice WWP	Plug in Socket	0.383	N	Alternative option
Seaton Sluice WWP	Portable Generator	0.002	N	Alternative option
Seaton Sluice WWP	Upsized UPS	0.143	Y	Alternative option
Sedgeletch STW Inlet WWP	Fixed Standby Generator	0.837	N	Preferred option
Sedgeletch STW Inlet WWP	Plug in Socket	0.383	N	Alternative option
Sedgeletch STW Inlet WWP	Portable Generator	0.002	N	Alternative option
Sedgeletch STW Inlet WWP	Upsized UPS	0.140	Y	Alternative option
Skinningrove WWP	Fixed Standby Generator	0.879	N	Preferred option
Skinningrove WWP	Plug in Socket	0.383	N	Alternative option
Skinningrove WWP	Portable Generator	0.002	N	Alternative option
Skinningrove WWP	Upsized UPS	0.142	Y	Alternative option
Snowdon Road WWP	Fixed Standby Generator	0.308	N	Preferred option
Snowdon Road WWP	Plug in Socket	0.392	N	Alternative option
Snowdon Road WWP	Portable Generator	0.013	N	Alternative option

Site Name	Option	Value NPV £M	Least Cost	Chosen Option
Snowdon Road WWP	Upsized UPS	0.146	Y	Alternative option
South Hylton St	Fixed Standby Generator	1.611	N	Preferred option
South Hylton St	Plug in Socket	0.485	N	Alternative option
South Hylton St	Portable Generator	1.034	N	Alternative option
South Hylton St	Upsized UPS	0.174	Y	Alternative option
St Peters WWP	Fixed Standby Generator	5.419	N	Preferred option
St Peters WWP	Plug in Socket	1.940	N	Alternative option
St Peters WWP	Portable Generator	1.814	N	Alternative option
St Peters WWP	Upsized UPS	0.658	Y	Alternative option
Swainby STW	Fixed Standby Generator	1.521	N	Preferred option
Swainby STW	Plug in Socket	0.442	N	Alternative option
Swainby STW - Power Resilience	Portable Generator	0.988	N	Alternative option
Swainby STW	Upsized UPS	0.172	Y	Alternative option
Swarland Fence WWP	Fixed Standby Generator	1.015	N	Preferred option
Swarland Fence WWP	Plug in Socket	0.395	N	Alternative option
Swarland Fence WWP	Portable Generator	0.019	N	Alternative option
Swarland Fence WWP	Upsized UPS	0.151	Y	Alternative option
The Lee, Rothbury (Embleton Ter.)	Fixed Standby Generator	1.611	N	Preferred option
The Lee, Rothbury (Embleton Ter.)	Plug in Socket	0.485	N	Alternative option
The Lee, Rothbury (Embleton Ter.)	Portable Generator	1.034	N	Alternative option
The Lee, Rothbury (Embleton Ter.)	Upsized UPS	0.174	Y	Alternative option
The Old Forge Ladgate Lane WWP	Fixed Standby Generator	1.507	N	Preferred option
The Old Forge Ladgate Lane WWP	Plug in Socket	0.434	N	Alternative option
The Old Forge Ladgate Lane WWP	Portable Generator	0.603	N	Alternative option
The Old Forge Ladgate Lane WWP	Upsized UPS	0.150	Y	Alternative option
Thorpe Street Hartlepool WWP	Fixed Standby Generator	0.984	N	Preferred option
Thorpe Street Hartlepool WWP	Plug in Socket	0.404	N	Alternative option
Thorpe Street Hartlepool WWP	Portable Generator	0.036	N	Alternative option
Thorpe Street Hartlepool WWP	Upsized UPS	0.151	Y	Alternative option
Throstles Nest WWP	Fixed Standby Generator	0.836	N	Preferred option
Throstles Nest WWP	Plug in Socket	0.383	N	Alternative option
Throstles Nest WWP	Portable Generator	0.002	N	Alternative option
Throstles Nest WWP	Upsized UPS	0.140	Y	Alternative option
University STW	Fixed Standby Generator	1.490	N	Preferred option
University STW	Plug in Socket	0.435	N	Alternative option
University STW	Portable Generator	0.434	N	Alternative option
University STW	Upsized UPS	0.170	Y	Alternative option
West Cornforth WWP	Fixed Standby Generator	0.983	N	Preferred option
West Cornforth WWP	Plug in Socket	0.394	N	Alternative option

Site Name	Option	Value NPV £M	Least Cost	Chosen Option
West Cornforth WWP	Portable Generator	0.019	N	Alternative option
West Cornforth WWP	Upsized UPS	0.150	Y	Alternative option
Whitburn Steel WWP	Fixed Standby Generator	1.242	N	Preferred option
Whitburn Steel WWP	Plug in Socket	0.703	N	Alternative option
Whitburn Steel WWP	Portable Generator	-0.212	N	Alternative option
Whitburn Steel WWP	Upsized UPS	0.250	Y	Alternative option
Woodham Bridge WWP	Fixed Standby Generator	1.162	N	Preferred option
Woodham Bridge WWP	Plug in Socket	0.441	N	Alternative option
Woodham Bridge WWP	Portable Generator	0.114	N	Alternative option
Woodham Bridge WWP	Upsized UPS	0.145	Y	Alternative option

TABLE 39: NET PRESENT VALUES AND SELECTED OPTIONS FOR WASTEWATER - FLOOD RESILIENCE

Site Name	Option	Value NPV £M	Least Cost	Chosen Option
Allendale STW	High Risk, Medium PE Class	-0.074	N	Alternative option
Allendale STW	High Risk, Medium PE Class - No Bunding	0.026	Y	Preferred option
Alnwick STW	Low Risk, Large PE Class	-0.151	N	Alternative option
Alnwick STW	Low Risk, Large PE Class - No Bunding	0.043	Y	Preferred option
Amble STW	Low Risk, Large PE Class	-0.151	N	Alternative option
Amble STW	Low Risk, Large PE Class - No Bunding	0.043	Y	Preferred option
Atlas Wynd WWP	High Risk, Medium PE Class	0.070	N	Alternative option
Atlas Wynd WWP	High Risk, Medium PE Class - No Bunding	0.170	Y	Preferred option
Aycliffe STW	High Risk, Large PE Class	-0.154	N	Alternative option
Aycliffe STW	High Risk, Large PE Class - No Bunding	0.040	Y	Preferred option
Aycliffe Woodham Bridge	Low Risk, Large PE Class	-0.134	N	Alternative option
Aycliffe Woodham Bridge	Low Risk, Large PE Class - No Bunding	0.060	Y	Preferred option
Ayton STW	High Risk, Medium PE Class	-0.074	N	Alternative option
Ayton STW	High Risk, Medium PE Class - No Bunding	0.026	Y	Preferred option
Bardon Mill (Redburn) Indirect WWP	High Risk, Small PE Class	-0.095	N	Alternative option
Bardon Mill (Redburn) Indirect WWP	High Risk, Small PE Class - No Bunding	0.004	Y	Preferred option
Bardon Mill STW	High Risk, Medium PE Class	-0.074	N	Alternative option
Bardon Mill STW	High Risk, Medium PE Class - No Bunding	0.026	Y	Preferred option
Barnard Castle	High Risk, Large PE Class	-0.157	N	Alternative option
Barnard Castle	High Risk, Large PE Class - No Bunding	0.037	Y	Preferred option
Beadnell Sea Outfall	Low Risk, Medium PE Class	-0.062	N	Alternative option
Beadnell Sea Outfall	Low Risk, Medium PE Class - No Bunding	0.038	Y	Preferred option
Belford STW	High Risk, Medium PE Class	-0.074	N	Alternative option
Belford STW	High Risk, Medium PE Class - No Bunding	0.026	Y	Preferred option
Bellingham STW	High Risk, Medium PE Class	-0.074	N	Alternative option
Bellingham STW	High Risk, Medium PE Class - No Bunding	0.026	Y	Preferred option
Belmont STW	Low Risk, Large PE Class	-0.151	N	Alternative option
Belmont STW	Low Risk, Large PE Class - No Bunding	0.043	Y	Preferred option
Berwick Upon Tweed STW	Low Risk, Large PE Class	-0.151	N	Alternative option
Berwick Upon Tweed STW	Low Risk, Large PE Class - No Bunding	0.043	Y	Preferred option
Billingham STW	Medium Risk, Large PE Class	-0.154	N	Alternative option
Billingham STW	Medium Risk, Large PE Class - No Bunding	0.040	Y	Preferred option
Birtley (Gateshead)	Medium Risk, Large PE Class	-0.154	N	Alternative option
Birtley (Gateshead)	Medium Risk, Large PE Class - No Bunding	0.040	Y	Preferred option
Blackhall Mill	High Risk, Medium PE Class	0.048	N	Alternative option
Blackhall Mill	High Risk, Medium PE Class - No Bunding	0.148	Y	Preferred option
Blyth	Low Risk, Large PE Class	-0.151	N	Alternative option

Site Name	Option	Value NPV £M	Least Cost	Chosen Option
Blyth	Low Risk, Large PE Class - No Bunding	0.043	Y	Preferred option
Brasside STW	High Risk, Medium PE Class	-0.074	N	Alternative option
Brasside STW	High Risk, Medium PE Class - No Bunding	0.026	Y	Preferred option
Bridge Street	High Risk, Small PE Class	-0.083	N	Alternative option
Bridge Street	High Risk, Small PE Class - No Bunding	0.017	Y	Preferred option
Browns Point A44	Low Risk, Large PE Class	-0.110	N	Alternative option
Browns Point A44	Low Risk, Large PE Class - No Bunding	0.084	Y	Preferred option
Butterknowle STW	High Risk, Medium PE Class	-0.074	N	Alternative option
Butterknowle STW	High Risk, Medium PE Class - No Bunding	0.026	Y	Preferred option
Cambois STW	Medium Risk, Large PE Class	-0.154	N	Alternative option
Cambois STW	Medium Risk, Large PE Class - No Bunding	0.040	Y	Preferred option
Cheveley Park WWP	High Risk, Small PE Class	-0.095	N	Alternative option
Cheveley Park WWP	High Risk, Small PE Class - No Bunding	0.004	Y	Preferred option
Cockfield STW	Low Risk, Medium PE Class	-0.071	N	Alternative option
Cockfield STW	Low Risk, Medium PE Class - No Bunding	0.028	Y	Preferred option
Coniscliffe Road	High Risk, Medium PE Class	-0.057	N	Alternative option
Coniscliffe Road	High Risk, Medium PE Class - No Bunding	0.043	Y	Preferred option
Corbridge WWP	High Risk, Medium PE Class	-0.074	N	Alternative option
Corbridge WWP	High Risk, Medium PE Class - No Bunding	0.026	Y	Preferred option
Cramlington STW	Low Risk, Large PE Class	-0.151	N	Alternative option
Cramlington STW	Low Risk, Large PE Class - No Bunding	0.043	Y	Preferred option
Crimdon Dene WWP	High Risk, Medium PE Class	-0.072	N	Alternative option
Crimdon Dene WWP	High Risk, Medium PE Class - No Bunding	0.027	Y	Preferred option
Crookhall STW	Medium Risk, Large PE Class	-0.154	N	Alternative option
Crookhall STW	Medium Risk, Large PE Class - No Bunding	0.040	Y	Preferred option
East Sleekburn	Low Risk, Medium PE Class	-0.071	N	Alternative option
East Sleekburn	Low Risk, Medium PE Class - No Bunding	0.028	Y	Preferred option
East Tanfield	Low Risk, Large PE Class	-0.151	N	Alternative option
East Tanfield	Low Risk, Large PE Class - No Bunding	0.043	Y	Preferred option
Elemore Vale Ps	High Risk, Small PE Class	-0.095	N	Alternative option
Elemore Vale Ps	High Risk, Small PE Class - No Bunding	0.004	Y	Preferred option
Embleton STW	Low Risk, Medium PE Class	-0.071	N	Alternative option
Embleton STW	Low Risk, Medium PE Class - No Bunding	0.028	Y	Preferred option
Fatfield P.Station	High Risk, Large PE Class	-0.128	N	Alternative option
Fatfield P.Station	High Risk, Large PE Class - No Bunding	0.066	Y	Preferred option
Felton STW	High Risk, Medium PE Class	-0.074	N	Alternative option
Felton STW	High Risk, Medium PE Class - No Bunding	0.026	Y	Preferred option
Ferryhill North STW	High Risk, Medium PE Class	-0.074	N	Alternative option
Ferryhill North STW	High Risk, Medium PE Class - No Bunding	0.026	Y	Preferred option

Site Name	Option	Value NPV £M	Least Cost	Chosen Option
Gainford STW	High Risk, Medium PE Class	-0.074	N	Alternative option
Gainford STW	High Risk, Medium PE Class - No Bunding	0.026	Y	Preferred option
Gordon Terrace Ferryhill WWP	Medium Risk, Large PE Class	-0.154	N	Alternative option
Gordon Terrace Ferryhill WWP	Medium Risk, Large PE Class - No Bunding	0.040	Y	Preferred option
Great Broughton STW	High Risk, Medium PE Class	-0.074	N	Alternative option
Great Broughton STW	High Risk, Medium PE Class - No Bunding	0.026	Y	Preferred option
Haltwhistle STW	High Risk, Medium PE Class	-0.074	N	Alternative option
Haltwhistle STW	High Risk, Medium PE Class - No Bunding	0.026	Y	Preferred option
Haverton Hill WWP	High Risk, Small PE Class	-0.095	N	Alternative option
Haverton Hill WWP	High Risk, Small PE Class - No Bunding	0.004	Y	Preferred option
Hebburn (Marine Drive)	High Risk, Medium PE Class	-0.057	N	Alternative option
Hebburn (Marine Drive)	High Risk, Medium PE Class - No Bunding	0.043	Y	Preferred option
Hendon STW	Medium Risk, Large PE Class	-0.151	N	Alternative option
Hendon STW	Medium Risk, Large PE Class - No Bunding	0.043	Y	Preferred option
High Coniscliffe WWP	High Risk, Small PE Class	-0.095	N	Alternative option
High Coniscliffe WWP	High Risk, Small PE Class - No Bunding	0.004	Y	Preferred option
Horden STW	Medium Risk, Large PE Class	-0.151	N	Alternative option
Horden STW	Medium Risk, Large PE Class - No Bunding	0.043	Y	Preferred option
Howdon Secondary STW	Low Risk, Large PE Class	-0.148	N	Alternative option
Howdon Secondary STW	Low Risk, Large PE Class - No Bunding	0.046	Y	Preferred option
Howdon Secondary STW_WWP	Low Risk, Medium PE Class	-0.069	N	Alternative option
Howdon Secondary STW_WWP	Low Risk, Medium PE Class - No Bunding	0.030	Y	Preferred option
Hummersnot WWP	High Risk, Small PE Class	-0.095	N	Alternative option
Hummersnot WWP	High Risk, Small PE Class - No Bunding	0.004	Y	Preferred option
Hurworth Place WWP	High Risk, Medium PE Class	-0.055	N	Alternative option
Hurworth Place WWP	High Risk, Medium PE Class - No Bunding	0.045	Y	Preferred option
Hustledown STW	Medium Risk, Large PE Class	-0.154	N	Alternative option
Hustledown STW	Medium Risk, Large PE Class - No Bunding	0.040	Y	Preferred option
Hutton Rudby	Low Risk, Medium PE Class	-0.071	N	Alternative option
Hutton Rudby	Low Risk, Medium PE Class - No Bunding	0.028	Y	Preferred option
Hutton Rudby WWP	High Risk, Medium PE Class	-0.072	N	Alternative option
Hutton Rudby WWP	High Risk, Medium PE Class - No Bunding	0.027	Y	Preferred option
Knitsley STW	Low Risk, Large PE Class	-0.151	N	Alternative option
Knitsley STW	Low Risk, Large PE Class - No Bunding	0.043	Y	Preferred option
Lanchester STW	Low Risk, Medium PE Class	-0.071	N	Alternative option
Lanchester STW	Low Risk, Medium PE Class - No Bunding	0.028	Y	Preferred option
Land At Cargo Fleet Middlesbrough	Low Risk, Large PE Class	-0.108	N	Alternative option

Site Name	Option	Value NPV £M	Least Cost	Chosen Option
Land At Cargo Fleet Middlesbrough	Low Risk, Large PE Class - No Bunding	0.086	Y	Preferred option
Leamside STW	Low Risk, Medium PE Class	-0.071	N	Alternative option
Leamside STW	Low Risk, Medium PE Class - No Bunding	0.028	Y	Preferred option
Levenside No.2 WWP	High Risk, Medium PE Class	-0.057	N	Alternative option
Levenside No.2 WWP	High Risk, Medium PE Class - No Bunding	0.043	Y	Preferred option
Low Coniscliffe WWP	High Risk, Medium PE Class	-0.033	N	Alternative option
Low Coniscliffe WWP	High Risk, Medium PE Class - No Bunding	0.067	Y	Preferred option
Low Wadsworth STW	High Risk, Large PE Class	-0.157	N	Alternative option
Low Wadsworth STW	High Risk, Large PE Class - No Bunding	0.037	Y	Preferred option
Lynemouth STW	High Risk, Large PE Class	-0.157	N	Alternative option
Lynemouth STW	High Risk, Large PE Class - No Bunding	0.037	Y	Preferred option
Melsonby STW	Low Risk, Medium PE Class	-0.071	N	Alternative option
Melsonby STW	Low Risk, Medium PE Class - No Bunding	0.028	Y	Preferred option
Middleton One Row STW	High Risk, Medium PE Class	-0.057	N	Alternative option
Middleton One Row STW	High Risk, Medium PE Class - No Bunding	0.043	Y	Preferred option
Middleton-In-Teesdale	High Risk, Medium PE Class	-0.074	N	Alternative option
Middleton-In-Teesdale	High Risk, Medium PE Class - No Bunding	0.026	Y	Preferred option
Milk Market WWP	Low Risk, Large PE Class	-0.102	N	Alternative option
Milk Market WWP	Low Risk, Large PE Class - No Bunding	0.092	Y	Preferred option
Morpeth STW	Medium Risk, Large PE Class	-0.154	N	Alternative option
Morpeth STW	Medium Risk, Large PE Class - No Bunding	0.040	Y	Preferred option
New Moors STW	Low Risk, Medium PE Class	-0.071	N	Alternative option
New Moors STW	Low Risk, Medium PE Class - No Bunding	0.028	Y	Preferred option
Newbiggin By The Sea STW	High Risk, Large PE Class	-0.154	N	Alternative option
Newbiggin By The Sea STW	High Risk, Large PE Class - No Bunding	0.040	Y	Preferred option
Newton Hall Ps No.1 (Salisbury R)	High Risk, Medium PE Class	-0.055	N	Alternative option
Newton Hall Ps No.1 (Salisbury R)	High Risk, Medium PE Class - No Bunding	0.045	Y	Preferred option
Newton Hall Ps No.2 (Lindisfarne)	High Risk, Medium PE Class	-0.057	N	Alternative option
Newton Hall Ps No.2 (Lindisfarne)	High Risk, Medium PE Class - No Bunding	0.043	Y	Preferred option
North Tees WWP	High Risk, Small PE Class	-0.092	N	Alternative option
North Tees WWP	High Risk, Small PE Class - No Bunding	0.008	Y	Preferred option
Pattinson South Ps	Low Risk, Medium PE Class	-0.039	N	Alternative option
Pattinson South Ps	Low Risk, Medium PE Class - No Bunding	0.061	Y	Preferred option
Patton Way Pegswood	High Risk, Medium PE Class	-0.048	N	Alternative option
Patton Way Pegswood	High Risk, Medium PE Class - No Bunding	0.052	Y	Preferred option
Pegswood STW	Low Risk, Medium PE Class	-0.071	N	Alternative option
Pegswood STW	Low Risk, Medium PE Class - No Bunding	0.028	Y	Preferred option

Site Name	Option	Value NPV £M	Least Cost	Chosen Option
Pittington STW	Medium Risk, Medium PE Class	-0.071	N	Alternative option
Pittington STW	Medium Risk, Medium PE Class - No Bunding	0.028	Y	Preferred option
Plawsworth STW	High Risk, Medium PE Class	-0.074	N	Alternative option
Plawsworth STW	High Risk, Medium PE Class - No Bunding	0.026	Y	Preferred option
Portrack STW	Low Risk, Large PE Class	-0.151	N	Alternative option
Portrack STW	Low Risk, Large PE Class - No Bunding	0.043	Y	Preferred option
Potto	High Risk, Small PE Class	-0.093	N	Alternative option
Potto	High Risk, Small PE Class - No Bunding	0.006	Y	Preferred option
Ramshaw STW	High Risk, Medium PE Class	-0.074	N	Alternative option
Ramshaw STW	High Risk, Medium PE Class - No Bunding	0.026	Y	Preferred option
Red Row Pumping Station	High Risk, Large PE Class	-0.138	N	Alternative option
Red Row Pumping Station	High Risk, Large PE Class - No Bunding	0.056	Y	Preferred option
Rennington WWP	High Risk, Small PE Class	-0.093	N	Alternative option
Rennington WWP	High Risk, Small PE Class - No Bunding	0.006	Y	Preferred option
Roker Gill Ps	High Risk, Large PE Class	-0.138	N	Alternative option
Roker Gill Ps	High Risk, Large PE Class - No Bunding	0.056	Y	Preferred option
Rothbury-Aln D C-WWP	High Risk, Small PE Class	-0.095	N	Alternative option
Rothbury-Aln D C-WWP	High Risk, Small PE Class - No Bunding	0.004	Y	Preferred option
Rowlands Gill Lochaugh STW	Low Risk, Large PE Class	-0.151	N	Alternative option
Rowlands Gill Lochaugh STW	Low Risk, Large PE Class - No Bunding	0.043	Y	Preferred option
Seaham Hall (Byrons Walk) Ps	High Risk, Small PE Class	-0.095	N	Alternative option
Seaham Hall (Byrons Walk) Ps	High Risk, Small PE Class - No Bunding	0.004	Y	Preferred option
Seaham STW	High Risk, Large PE Class	-0.157	N	Alternative option
Seaham STW	High Risk, Large PE Class - No Bunding	0.037	Y	Preferred option
Seaham(Northlea) Ps	High Risk, Medium PE Class	-0.057	N	Alternative option
Seaham(Northlea) Ps	High Risk, Medium PE Class - No Bunding	0.043	Y	Preferred option
Seaton Sluice Storages Tank	Low Risk, Large PE Class	-0.151	N	Alternative option
Seaton Sluice Storages Tank	Low Risk, Large PE Class - No Bunding	0.043	Y	Preferred option
Sedgeletch STW	Medium Risk, Large PE Class	-0.154	N	Alternative option
Sedgeletch STW	Medium Risk, Large PE Class - No Bunding	0.040	Y	Preferred option
Seghill No 1 (Deneside) - Indirect WWP	High Risk, Small PE Class	-0.095	N	Alternative option
Seghill No 1 (Deneside) - Indirect WWP	High Risk, Small PE Class - No Bunding	0.004	Y	Preferred option
Shilbottle STW	Low Risk, Medium PE Class	-0.071	N	Alternative option
Shilbottle STW	Low Risk, Medium PE Class - No Bunding	0.028	Y	Preferred option
Snowdon Road WWP	Low Risk, Large PE Class	-0.151	N	Alternative option
Snowdon Road WWP	Low Risk, Large PE Class - No Bunding	0.043	Y	Preferred option
Staindrop	High Risk, Medium PE Class	-0.074	N	Alternative option
Staindrop	High Risk, Medium PE Class - No Bunding	0.026	Y	Preferred option

Site Name	Option	Value NPV £M	Least Cost	Chosen Option
Startforth	High Risk, Small PE Class	-0.093	N	Alternative option
Startforth	High Risk, Small PE Class - No Bunding	0.006	Y	Preferred option
Stokesley Levenside WWP	High Risk, Medium PE Class	-0.057	N	Alternative option
Stokesley Levenside WWP	High Risk, Medium PE Class - No Bunding	0.043	Y	Preferred option
Stokesley STW	High Risk, Large PE Class	-0.157	N	Alternative option
Stokesley STW	High Risk, Large PE Class - No Bunding	0.037	Y	Preferred option
Stonebridge STW	High Risk, Medium PE Class	-0.057	N	Alternative option
Stonebridge STW	High Risk, Medium PE Class - No Bunding	0.043	Y	Preferred option
Sunderland Bridge STW	High Risk, Medium PE Class	-0.074	N	Alternative option
Sunderland Bridge STW	High Risk, Medium PE Class - No Bunding	0.026	Y	Preferred option
Sunnybrow Pump.Stat.	High Risk, Medium PE Class	-0.057	N	Alternative option
Sunnybrow Pump.Stat.	High Risk, Medium PE Class - No Bunding	0.043	Y	Preferred option
Swainby	High Risk, Medium PE Class	-0.074	N	Alternative option
Swainby	High Risk, Medium PE Class - No Bunding	0.026	Y	Preferred option
Swarland Fence WWP	High Risk, Medium PE Class	-0.072	N	Alternative option
Swarland Fence WWP	High Risk, Medium PE Class - No Bunding	0.027	Y	Preferred option
Teesside Airport	Low Risk, Medium PE Class	-0.071	N	Alternative option
Teesside Airport	Low Risk, Medium PE Class - No Bunding	0.028	Y	Preferred option
The Tannery WWP	High Risk, Large PE Class	-0.140	N	Alternative option
The Tannery WWP	High Risk, Large PE Class - No Bunding	0.054	Y	Preferred option
Togston STW	Low Risk, Medium PE Class	-0.071	N	Alternative option
Togston STW	Low Risk, Medium PE Class - No Bunding	0.028	Y	Preferred option
Tursdale WWP	High Risk, Small PE Class	-0.095	N	Alternative option
Tursdale WWP	High Risk, Small PE Class - No Bunding	0.004	Y	Preferred option
Warkworth No 3 (The Butts)-Aln D	High Risk, Medium PE Class	-0.055	N	Alternative option
Warkworth No 3 (The Butts)-Aln D	High Risk, Medium PE Class - No Bunding	0.045	Y	Preferred option
Washington STW	Low Risk, Large PE Class	-0.148	N	Alternative option
Washington STW	Low Risk, Large PE Class - No Bunding	0.046	Y	Preferred option
West Cornforth STW	High Risk, Medium PE Class	-0.072	N	Alternative option
West Cornforth STW	High Risk, Medium PE Class - No Bunding	0.027	Y	Preferred option
Willow Green STW	High Risk, Medium PE Class	-0.074	N	Alternative option
Willow Green STW	High Risk, Medium PE Class - No Bunding	0.026	Y	Preferred option
Witton Gilbert STW	High Risk, Large PE Class	-0.157	N	Alternative option
Witton Gilbert STW	High Risk, Large PE Class - No Bunding	0.037	Y	Preferred option
Worsall Road WWP	High Risk, Large PE Class	-0.140	N	Alternative option
Worsall Road WWP	High Risk, Large PE Class - No Bunding	0.054	Y	Preferred option

TABLE 9: NET PRESENT VALUES AND SELECTED OPTIONS FOR WATER POWER

Site Name	Option	Value NPV £M	Least Cost	Chosen Option
Bleach Green Borehole *	Fixed Standby Generator	-0.029	N	Preferred option
Bleach Green Borehole	Plug in Socket	-0.041	N	Alternative option
Bleach Green Borehole	Portable Generator	-0.090	N	Alternative option
Langford *	Fixed Standby Generator	2.691	N	Preferred option
Langford	Plug in Socket	-0.126	N	Alternative option
Langford	Portable Generator	-0.090	N	Alternative option
Murton (Thornton Main) WTW	Fixed Standby Generator	0.507	N	Preferred option
Murton (Thornton Main) WTW	Portable Generator	-0.090	N	Alternative option
Ormesby *	Fixed Standby Generator	3.693	N	Preferred option
Ormesby	Plug in Socket	-0.109	N	Alternative option
Ormesby	Portable Generator	-0.091	N	Alternative option
Warkworth	Fixed Standby Generator	5.459	N	Preferred option
Warkworth	Plug in Socket	-0.164	N	Alternative option
Warkworth	Portable Generator	-0.091	N	Alternative option
Wortham Bore *	Fixed Standby Generator	0.236	N	Preferred option
Wortham Bore	Plug in Socket	-0.041	N	Alternative option
Wortham Bore	Portable Generator	-0.090	N	Alternative option

One site (Bleach Green) with a marginally -ve NPV has been proposed for investment as our CBA calculations do not account for the effects of Growth – which would be expected to turn the NPV positive if included.

The NPV values above are calculated using a baseline assumption of power related site outage occurring in future every 5 years. In Table 35 we undertake analysis to demonstrate that a. this assumption is conservative compared to a. the data gathered as part of our site by site resilience vulnerability assessment and also b. in relation to the expected current and future frequencies of storms which have the potential to disrupt power supplies as per independent climate analysis.

TABLE 40: INFORMATION SUPPORTING POWER OUTAGE FREQUENCY ASSUMPTIONS

Site Name	Historic Power Loss Frequency from Site Resilience Assessment	Power loss related Outage Potential from Site Resilience Assessment*	% of customers without supply during outage if all current mitigations deployed	Current frequency of weather patterns associated with storms with potential to trigger power loss (pa) (See table 10 and 11)	Future frequency of storms with potential to trigger power loss (pa)	Outage assessment used for CBA/NPV
Bleach Green	At least 1 pa	12 hours	Up to 50%	16.8	18.1	1 per 5 years, 6-12 hour duration, 10% of customers affected
Langford	At least 1 pa	72 hours	Up to 10%	16.8	18.1	1 per 5 years, 24 hour duration, 5% of customers affected
Murton	3-4 times over 5 yrs	24 hours	Up to 25%	17.5	19.0	1 per 10 years,12-24 hour duration, 10% of customers affected
Ormesby	At least 1 pa	72 hours	50% +	16.8	18.1	1 per 5 years,24 hour duration, 10% of customers affected
Warkworth	At least 1 pa	72 hours	50% +	17.5	19.0	1 per 5 years, 24 hour duration, 10% of customers affected
Wortham	At least 1 pa	12 hours	50% +	16.8	18.1	1 per 5 years, 6-12 hour duration, 10% of customers affected

* Noting not all power loss incidents will trigger an outage of this scale.

TABLE 41: SITE BY SITE INTERRUPTIONS AND CRI IMPACTS ASSUMED IN BASELINE POSITION IN THE EVENT OF AN OUTAGE

Site Name	Interruptions Impact in Event of Outage	CRI Impact in Event of Outage
Bleach Green	Y	Y – a borehole site so turbidity levels v susceptible to power outages
Langford	N – A major site so would be prioritised for resolution in the event of a major / region wide outage	N
Murton	Y	N
Ormesby	N – A major site so would be prioritised for resolution in the event of a major / region wide outage	N
Warkworth	N – A major site so would be prioritised for resolution in the event of a major / region wide outage	N
Wortham	Y	Y – a borehole site so turbidity levels v susceptible to power outages

TABLE 42: NET PRESENT VALUES AND SELECTED OPTIONS FOR WATER - FLOOD RESILIENCE

Site Name	Option	Value NPV £M	Least Cost	Chosen Option
Barsham WTW	N/A – Single option	N/A		Alternative option
Barsham WTW	Tank 3 site buildings	1.185		Preferred option
Bay Bridge WTW	N/A – Single option	N/A		Alternative option
Bay Bridge WTW	Tank building, install flood doors, seal vents and raise height of switchgear	-0.008		Preferred option
Benhall WTW	N/A – Single option	N/A		Alternative option
Benhall WTW	Tank building, install flood doors, seal vents and raise height of switchgear	0.396		Preferred option
Coldfair Green WTW	N/A – Single option	N/A		Alternative option
Coldfair Green WTW	Tank building, install flood doors, seal vents and raise height of switchgear	-0.002		Preferred option
Coxhoe WPS	N/A – Single option	N/A		Alternative option
Coxhoe WPS	Tank building, install flood doors, seal vents and raise height of switchgear	0.036		Preferred option
Matfen WTW	N/A – Single option	N/A		Alternative option
Matfen WTW	Tank building, install flood doors, seal vents and raise height of switchgear	0.345		Preferred option
Stifford WTW	N/A – Single option	N/A		Alternative option
Stifford WTW	Tank building, install flood doors, seal vents and raise height of switchgear	0.189		Preferred option

Two sites with a marginally -ve NPV have been proposed for investment as our CBA calculations do not account for the effects of growth, which would be expected to turn the NPV positive if included.

TABLE 43: SITE BY SITE FLOOD RISK ASSESSMENTS USED TO DETERMINE BASELINE OUTAGE FREQUENCIES

Site Name	Future Flood Risk
Barsham WTW	1:75 yrs
Bay Bridge WTW	1:30 yrs
Benhall WTW	1:75 yrs
Coldfair Green WTW	1:75 yrs
Coxhoe WPS	1:100 yrs
Matfen WTW	1:30 yrs
Stifford WTW	1:75 yrs

Source: Datasets underpinning Mott Macdonald Climate Analysis

9. APPENDIX D - AMP7 RESILIENCE SITES

TABLE 44: AMP7 RESILIENCE SITES FOR WATER

Site	Risk	Resilience Type
Birney Hill P.S.	HIGH	FLOODING (H)
		LOSS OF POWER (M)
Broken Scar PS	MODERATE	FLOODING (M)
		LOSS OF POWER (M)
Broken Scar River Intake Pumps	HIGH	FLOODING (H)
		LOSS OF POWER (M)
Broken Scar TW	HIGH	LOSS OF POWER (M)
Ormesby PS	HIGH	FLOODING (H)
Barsham final contact tank	HIGH	FLOODING (H)
Barsham PS1	MODERATE	FLOODING (M)
Chigwell Raw Water PS	HIGH	FLOODING (M)
Chigwell Treated Water PS	HIGH	FLOODING (M)
Hanningfield	HIGH	FLOODING (H)
Layer	HIGH	FLOODING (H)
Layer High Lift	HIGH	FLOODING (H)
Lower Hall PS	HIGH	LOSS OF POWER (M)
Ormesby Paterson Stream	HIGH	FLOODING (H)

TABLE 45: AMP7 SITES FOR WASTEWATER

Site	Asset Type
Acomb SPS	Sewage pumping station
Aldbrough SPS	Sewage pumping station
Aldbrough STW	Sewage treatment works
Aldin Grange STW	Sewage treatment works
Alnmouth SPS	Sewage pumping station
Alston STW	Sewage treatment works
Anick Grange SPS	Sewage pumping station
Ashington Business Park SPS	Sewage pumping station
Atlas Wynd SPS	Sewage pumping station
Barkers Haugh STW	Sewage treatment works
Barkers Haugh STWSPS	Sewage pumping station
Barton STW	Sewage treatment works
Billingham STW	Sewage treatment works
Bishop Auckland STW	Sewage treatment works
Bishopton STW	Sewage treatment works
Blyth No5 SPS	Sewage pumping station
Blyth No9 SPS	Sewage pumping station
Bowburn STW	Sewage treatment works
Bradbury RBC	Sewage treatment works
Brenda Road STW	Sewage treatment works
Broom Haugh STW	Sewage treatment works
Browney STW	Sewage treatment works
Burnmoor Drive SPS	Sewage pumping station
Castle Eden	Sewage treatment works
Chester Le Street STW	Sewage treatment works
Chester Le Street STW SPS	Sewage pumping station
Chilton Lane SPS	Sewage pumping station
Chilton Lane STW	Sewage treatment works
Cockfield STW	Sewage treatment works
Consett STW	Sewage treatment works
Copeland Row SPS	Sewage pumping station
Copperas Lane SPS Scotswood	Sewage pumping station
Cornhill On Tweed STW	Sewage treatment works
Cornhill SPS	Sewage pumping station
Cotherstone STW	Sewage treatment works
Cowpen SPS	Sewage pumping station
Craster North SPS	Sewage pumping station

Craster South SPS	Sewage pumping station
Croxdale SPS	Sewage pumping station
Dene Holme SPS	Sewage pumping station
Derwenthaugh SPS	Sewage pumping station
Diall Stobbs SPS	Sewage pumping station
East Tanfield Tps	Sewage pumping station
Edmondsley STW	Sewage treatment works
Eland Lane SPS	Sewage pumping station
Esh Winning STW	Sewage treatment works
Etal STW/SPS	Sewage pumping station
Felton STW	Sewage treatment works
Fishburn STW	Sewage treatment works
Forrest Gater SPS	Sewage pumping station
Fourstone STW	Sewage treatment works
Frosterley STW	Sewage treatment works
Hadston SPS East Cheviot	Sewage pumping station
Haydon Bridge STW	Sewage treatment works
Hepscott Park SPS	Sewage pumping station
Hexham STW	Sewage treatment works
High Newton SPS	Sewage pumping station
Hipsburn SPS	Sewage pumping station
Hummerbeck SPS	Sewage pumping station
Hutton Magma SPS	Sewage pumping station
Kelloe STW	Sewage treatment works
Lane Head SPS	Sewage pumping station
Low Stanners SPS	Sewage pumping station
Low Wadsworth STW	Sewage treatment works
Lumley SPS	Sewage pumping station
Lustrum SPS	Sewage pumping station
Melkridge SPS	Sewage pumping station
Melkridge STW	Sewage treatment works
Millfield STW	Sewage treatment works
Morpeth STW	Sewage treatment works
Netherton STW	Sewage treatment works
Newbiggin STW	Sewage treatment works
Newton Hall SPS	Sewage pumping station
Norham SPS	Sewage pumping station
Norham STW	Sewage treatment works
North Seaton SPS	Sewage pumping station
Old River Tees SPS	Sewage pumping station

Ouseburn East SPS	Sewage pumping station
Ouseburn West SPS	Sewage pumping station
Ovingham SPS	Sewage pumping station
Pelton SPS	Sewage pumping station
Peth Head SPS	Sewage pumping station
Pittington STW	Sewage treatment works
Pity Me STW	Sewage treatment works
Portrack SPS	Sewage pumping station
Powburn STW	Sewage treatment works
Princess Way SPS	Sewage pumping station
Ramshaw STW	Sewage treatment works
Riding Mill Village SPS	Sewage pumping station
Riverside Park SPS	Sewage pumping station
Rose Cottage SPS	Sewage pumping station
Rothbury STW	Sewage treatment works
Sacriston STW	Sewage treatment works
Saltburn SPS	Sewage pumping station
Seaburn SPS	Sewage pumping station
Seahouses Harbour SPS	Sewage pumping station
Seaton Carew Headworks SPS	Sewage pumping station
Sedgefield STW	Sewage treatment works
Sherburn House STW	Sewage treatment works
Sherburn STW	Sewage treatment works
Shincliffe Mill SPS	Sewage pumping station
Shincliffe Village SPS	Sewage pumping station
Southlands SPS	Sewage pumping station
Stanhope STW	Sewage treatment works
Steppy Lane SPS	Sewage pumping station
Stockton SPS Queensport Close	Sewage pumping station
Strawbery Terrace SPS	Sewage pumping station
Stressholme STW	Sewage treatment works
Studley Drive SPS	Sewage pumping station
Sunderland Bridge STW	Sewage treatment works
Swarland Fence SPS	Sewage pumping station
Tanfield Lea SPS	Sewage pumping station
Teesbridge SPS	Sewage pumping station
Temple House SPS	Sewage pumping station
The Staners SPS Corbridge	Sewage pumping station
Thorntons Close SPS	Sewage pumping station
Thorpe Street SPS	Sewage pumping station

Thorpe Thewles SPS	Sewage pumping station
Tilery SPS	Sewage pumping station
Tow Law STW	Sewage treatment works
Trimdon STW	Sewage treatment works
Tudhoe Mill STW	Sewage treatment works
Twizzel Burn SPS	Sewage pumping station
Tyne Green SPS	Sewage pumping station
Tyne Mills SPS	Sewage pumping station
University STW	Sewage treatment works
Wark SPS	Sewage pumping station
Wark STW	Sewage treatment works
Warkworth Stanners SPS	Sewage pumping station
Warrior Park SPS	Sewage pumping station
Washington STW	Sewage treatment works
West Street SPS	Sewage pumping station
Western Area STW	Sewage treatment works
Willington STW	Sewage treatment works
Windlestone STW	Sewage treatment works
Wolsingham STW	Sewage treatment works
Woodside Wynyard SPS	Sewage pumping station
Wooler Auction Mart SPS	Sewage pumping station
Wooler STW	Sewage treatment works
Yarm SPS	Sewage pumping station
Zetland Park SPS	Sewage pumping station