Our final plan

Our Drainage and Wastewater Management Plan 2025-2050

Technical Appendices

Appendix G – Adaptive Planning: ensuring our plan is future-proofed

May 2023

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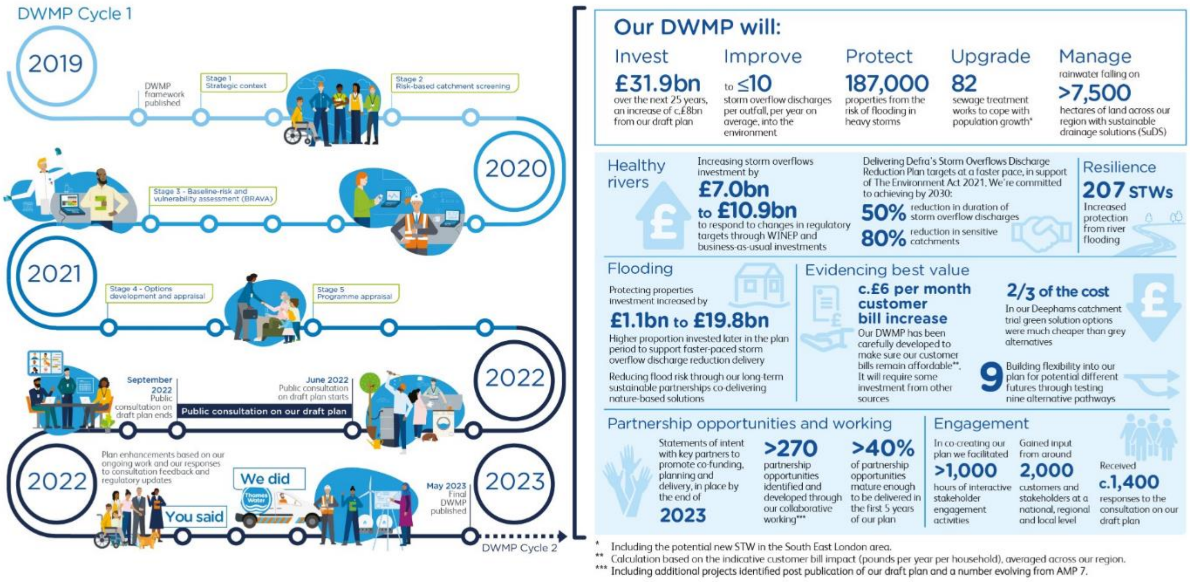
Preface

We're proud to present our first Drainage and Wastewater Management Plan (DWMP) and encouraged by the level of positive feedback we've received. Over the last four years, we've engaged and worked collaboratively with around 2,000 of our customers and stakeholders, to deepen our shared understanding and develop new ways to manage drainage and wastewater across our region. We illustrate our DWMP Cycle 1 and its headlines below.



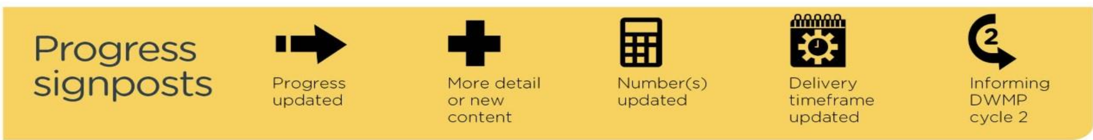
We've progressed and enhanced our DWMP since we published it for public consultation in June 2022. We were pleased to receive lots of positive comments and support on the quality and ambition of our draft plan as well as useful ideas for making our final DWMP even stronger.

We've updated our draft plan based on our ongoing DWMP work, regulatory updates and our responses to the consultation feedback wherever possible*. Our updates include providing more detail where you felt it was needed and creating new appendices to answer technical queries. For more details on how we've progressed our final plan and responded to the consultation feedback, please see our Non-technical summary and You said, We did Technical appendix.

* Some public consultation feedback didn't require further action or wasn't relevant to the DWMP process. Other feedback was relevant to future DWMP planning cycles and will be used to inform this work.

Progress signposts

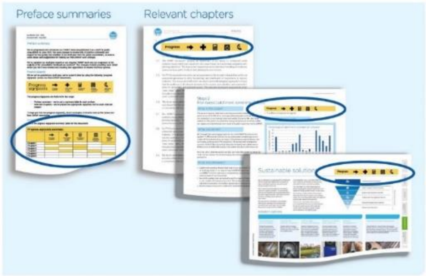
We want to make it easy for you to see what's changed. You can spot all the places we've updated our draft plan with our 'progress signposts' which we've used across our final DWMP documents.



Here's where they'll be:

- Preface summaries – we've put a summary table in each document's preface (excluding Summary documents and CSPs)
- Relevant chapters – we've placed the appropriate signposts next to each relevant chapter (including Summary document and CSPs)

To help you find our progress signposts, here are examples of what to look out for:



Progress summary table

The progress signposts summary table for the chapters in this document is outlined below. We've used orange cells to indicate where our draft plan has been updated with progress.

Progress signposts summary: Adaptive planning	Progress updated	More detail or new content	Number(s) updated	Delivery timeframe updated	Informing DWMP cycle 2
Adaptive planning at the heart of our DWMP					
What is adaptive planning and why do we need it?					
Testing different future scenarios and their impact on our preferred plan					
Understanding if and when we need to change our plan					
Conclusions					

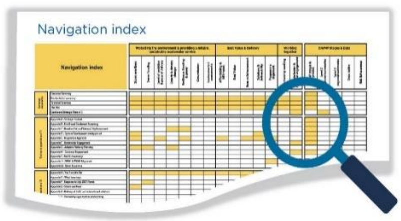
Key DWMP content

This document specifically includes the following key DWMP content:

- Protecting the environment and providing a reliable, sustainable wastewater service:
  - Storm overflows
  - Sewer flooding
  - Growth & climate change

Navigating our documents

To help you navigate around our final DWMP document suite and find where key DWMP content features, we've placed a Navigation index at the back of this document.



Executive Summary

What is a Drainage and Wastewater Management Plan?

A Drainage and Wastewater Management Plan (DWMP) is a long-term costed plan that is focused on partnership working, which sets out the future risks and pressures for our drainage and wastewater systems. It identifies the actions that are required to make sure we can continue to deliver our services reliably and sustainably, whilst also achieving positive outcomes for our customers, communities and environment. Where significant uncertainties are identified in developing the plan, the DWMP framework[1] recommends companies consider adaptive pathways in developing their preferred plan. Adaptive planning is central to Ofwat's guidance on long-term delivery strategies and common reference scenarios (2022)[2], which connects our DWMP with our medium-term business plans.

Adaptive planning

Adaptive planning provides a framework for exploring how sensitive a plan may be to alternative scenarios, risks and uncertainties, to ensure that the plan is flexible and resilient to different futures. The approach identifies where thresholds and trigger points for alternative adaptative pathways exist, providing the basis for monitoring and review of the strategy and interventions, mitigating the risk that short-term decision making might reduce or jeopardise choices in the future.

Following our consultation phase, we re-optimised our draft DWMP plan under a best value framework. We have derived a final preferred plan of £33.3bn[3] over the next 25 years to meet our long-term vision. In this Technical Appendix we show how we have tested this final plan against:

- A wide range of scenarios, aligning to Ofwat's common reference scenarios[2]
- Different future pathways to identify preferred and least regret (core) pathways
- Technological innovation scenarios for our key treatment works in London

From our testing of the preferred plan, we have identified the key factors that may drive different pathways. The following table shows that the sewer flooding and storm overflows investment is most sensitive to climate change forecasts as rainfall events have the most impact on hydraulic deficit. Our sewage treatment works compliance investment is most sensitive to population growth as these impacts on treatment load.

Therefore, uncertainty in climate change and demand forecasts has a significant impact on the long-term cost of the programme and/or change the pace of investment. In subsequent DWMP iterations this will be broadened to reflect factors such as deliverability, changing public opinions on environmental protection and affordability.

[1] Drainage and Wastewater Management Plans | Water UK
[2] PR24 and beyond: Final guidance on long-term delivery strategies - Ofwat
[3] All stated costs in this Technical Appendix include both construction and operating costs. Costs are presented at a 2020/21 price base, which aligns with costs submitted in the Ofwat data tables. Costs are subject to rounding; however, totals are correct.

	Key factors driving future uncertainty	Preferred plan (£bn)	Potential range of impact (£bn)	
			Low	High
Reducing storm overflow discharges	Climate change	11.8	11.4	14.8
Protecting properties from sewer flooding		20.2	18.7	21.1
Addressing sewage treatment works compliance risks	Demand (population growth)	1.4	1.1	1.4

Notes
1. A high global emissions climate change scenario may require over 25% more investment in the longer-term (up to 2050), to achieve our ambition of reducing storm overflow discharges.
2. Our programme of investments to protect properties from sewer flooding has used a 15% ('central estimate') forecast for the increase in rainfall intensity in severe storms, due to climate change, by 2050. However, this forecast could range between 8% (representing a low global emissions climate change scenario) and 20% (representing a high global emissions scenario). The scenarios align with the climate change common reference scenarios as defined in Ofwat's guidance on long-term delivery strategies. They are derived from Representative Concentration Pathways (RCPs)[4], which create forecasts based on different future greenhouse gas concentrations, Specifically, the low scenario is based on RCP 2.6 and the high scenario is based in RCP 8.5.
3. The current resident population served by our wastewater network is 15.5 million. This is forecast to reach 16 million in 2025. Between 2025 and 2050, the forecast increase in resident population in our region ranges from 0.5 million to 3 million, based on the low and high scenarios as defined in Ofwat's guidance on long-term delivery strategies.

Table 0-1 Key factors that may drive different pathways and their potential impact on our preferred plan

We have combined different climate change and population growth forecasts to determine realistic best (core) and worst case (adverse) future pathways as defined by Ofwat[2]. Our preferred plan in the near term tracks the core pathway. This pathway sets out the lowest requirement and, therefore, drives a programme of no- and low-regret investments, including investment in monitoring, investigations and other activities to ensure other options can be efficiently implemented should the need to switch pathways arise in the future.

Therefore, our preferred plan can be considered a no-regrets plan as it is based on the most certain climate change and population growth forecasts. Beyond 2040, significant climate change uplifts are forecast, and our preferred plan tracks a central position between the core and adverse forecasts. This enables us to more easily accelerate or decelerate the pace of the plan, retaining flexibility.

[4] For more information on RCPs, please refer to [ukcp18-guidance---representative-concentration-pathways.pdf (metoffice.gov.uk)](ukcp18-guidance---representative-concentration-pathways.pdf)

This principle is shown conceptually in the following diagram:

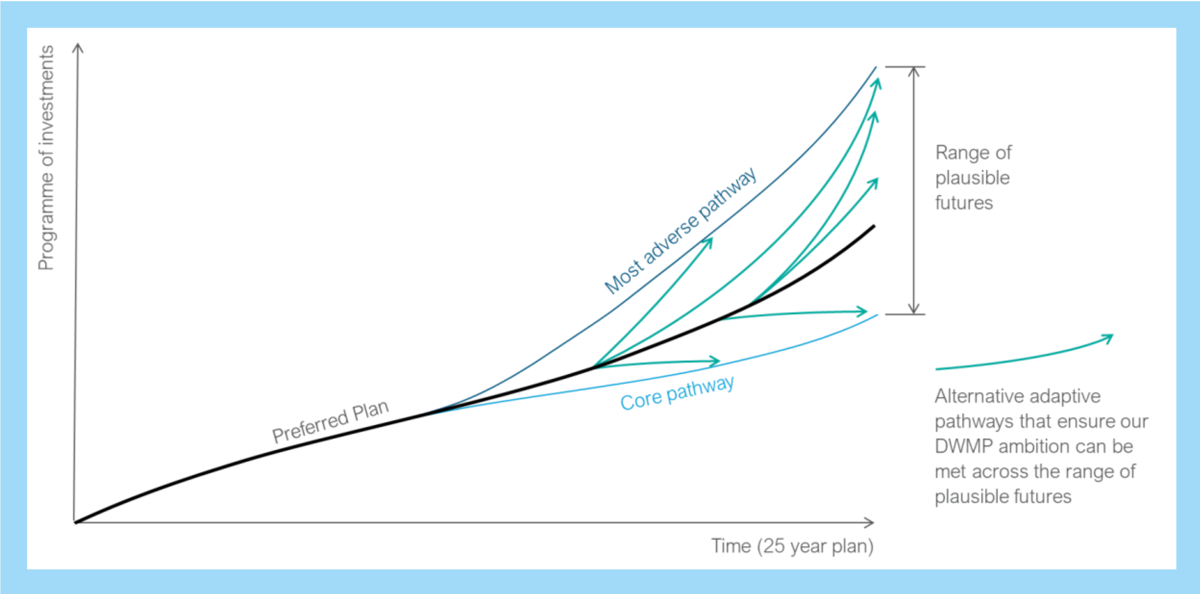


Figure 0-1 Illustration showing alternative pathways over a range of plausible futures

Adaptive planning: reducing storm overflow discharges and protecting properties from sewer flooding

The following graph illustrates the impact of different futures on our investment profile.

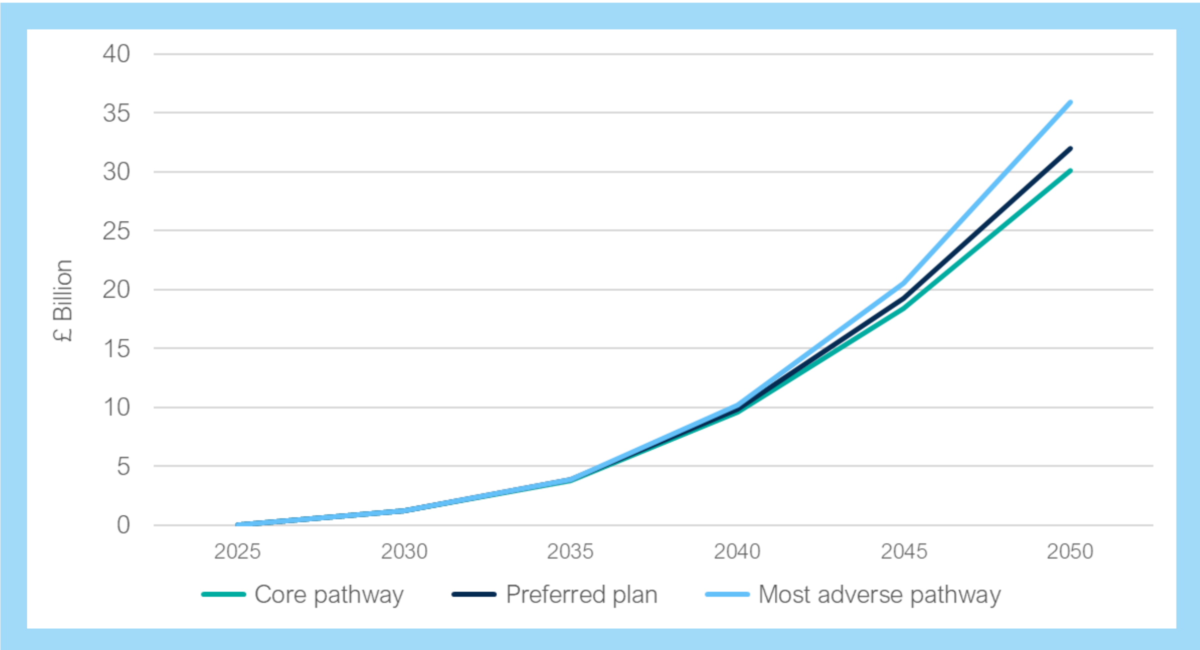


Figure 0-2 Impact of different futures on our investment profile (reducing storm overflow discharges and protecting properties from sewer flooding)

There is little difference between the overall cost to 2040 following any pathway; the departure in investment to address future drivers of uncertainty occurs between 2040 and 2050, principally due to significant divergence in the forecasts for climate change scenarios.

Between 2035 and 2040 we will need to decide whether to follow a new pathway, starting at 2040 (as this is time at which pathways begin to show significant divergence, driven by the forecast for climate change), or remain on the preferred plan pathway. Similar decisions will be required during the following planning period (2040-2045), depending on the pathway taken the previous planning period. UK climate projections are informed by the Met Office Hadley Centre Climate Programme and were last updated in 2018 (UKCP18). It is not known when the next refresh will be published but this is considered very likely to be in advance of our forecast trigger points prior to 2040.

Based on the above we have identified four alternative pathways to the preferred plan:

- Switch from the preferred plan to the worst case (most adverse) pathway in 2040
- Switch from the preferred plan to the best case (core) pathway in 2040
- Switch from the preferred plan to the worst case (most adverse) pathway in 2045
- Switch from the preferred plan to the best case (core) pathway in 2045

The figure below diagrammatically shows the alternative pathways for reducing storm overflow discharges and protecting properties from sewer flooding.

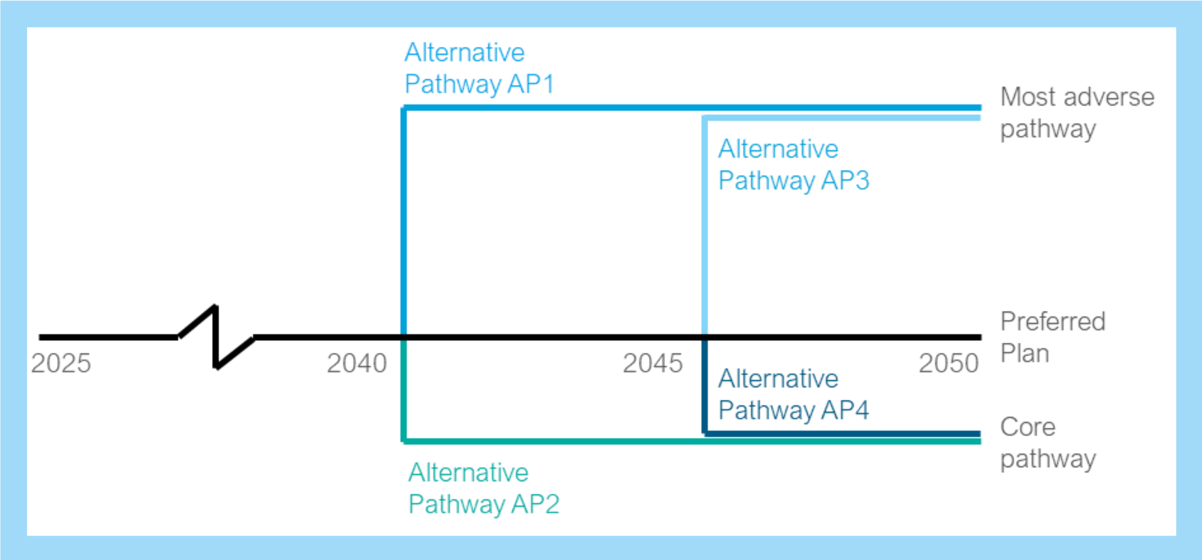


Figure 0-3 Alternative pathways diagram (reducing storm overflow discharges and protecting properties from sewer flooding)

The investment profiles of the alternative pathways, compared to our preferred plan, are tabulated below.

AP	Alternative pathway	Up to end 2030	Up to end 2035	Up to end 2040	Up to end 2045	Up to end 2050
	Preferred plan	1.2	3.8	9.8	19.3	31.9
1	Switch to the most adverse pathway in 2040	1.2	3.8	9.8	20.5	35.9
2	Switch to the core pathway in 2040	1.2	3.8	9.8	18.4	30.1
3	Switch to the most adverse pathway in 2045	1.2	3.8	9.8	19.3	35.9
4	Switch to the core pathway in 2045	1.2	3.8	9.8	19.3	30.1

Notes

1. Costs are presented cumulatively at a 2020/21 price base. The costs reflect those presented in the Ofwat data tables, noting that for the data tables, costs are presented per planning period and are split between reducing storm overflow discharges and protecting properties from sewer flooding.

Table 0-2 Cumulative cost of each alternative pathway (reducing storm overflow discharges and protecting properties from sewer flooding) (£bn)

Adaptive planning: addressing sewage treatment works compliance risks

The following graph summarises the impact of different futures on our investment profile.

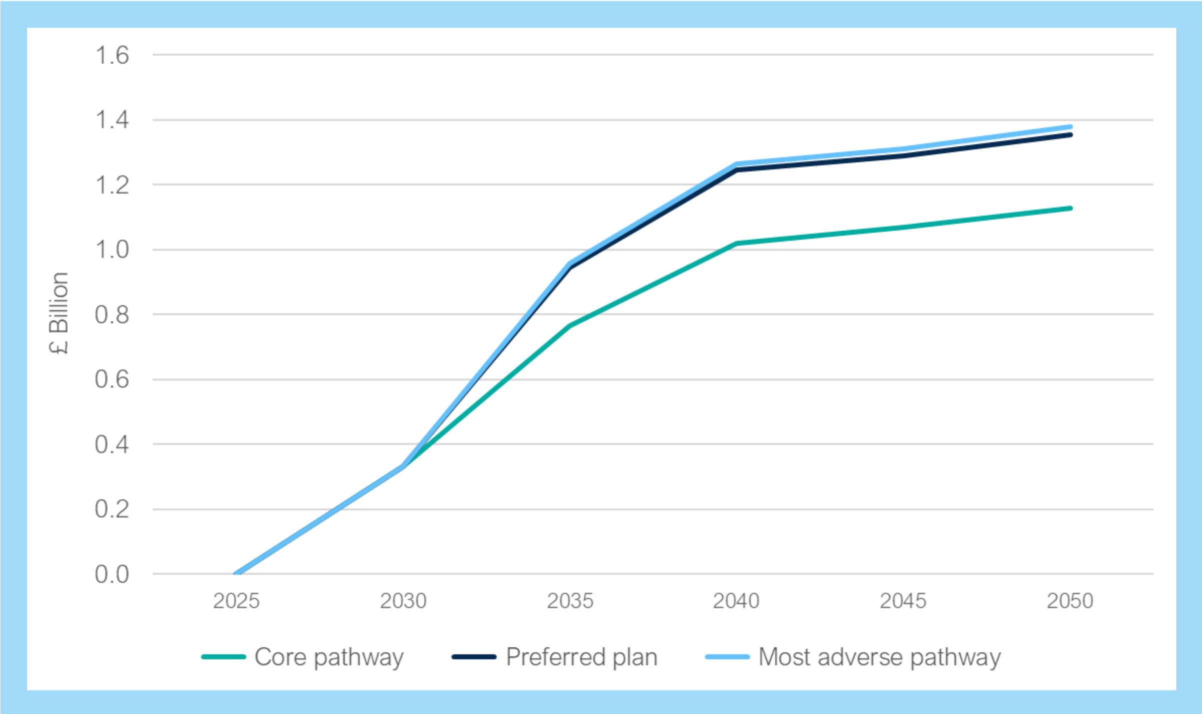


Figure 0-4 Impact of different futures on our investment profile (addressing sewage treatment works compliance risks)

We have experienced significant planning and development pressures in relation to high population growth areas in recent years (for example, current and future proposals for new developments in London's Isle of Dogs). We expect this trend to continue and as a result, are planning based on the most adverse pathway in the future. Modular design of sewage treatment works upgrades will allow us to accelerate or decelerate investment in line with actual growth.

We have identified one alternative pathway to the preferred plan to explore the impact of demand on future investment in treatment, acknowledging that there are likely to be a range of pathways to address site-specific issues and risks. Our alternative pathway represents a switch from the preferred plan to the best case (core) pathway in 2030, triggered by a change to demand forecasts.

The figure below diagrammatically shows the alternative pathway for addressing sewage treatment works compliance risks.

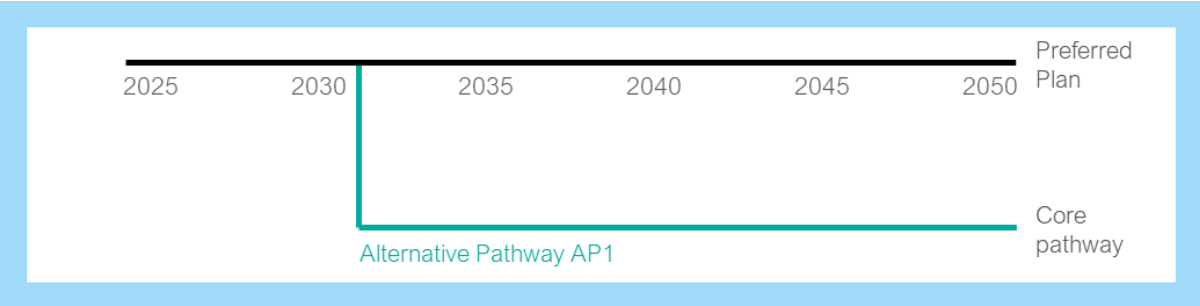


Figure 0-5 Alternative pathway diagram (addressing sewage treatment works compliance risks)

The investment profile of the alternative pathway, compared to our preferred plan, is tabulated below.

Alternative pathway		Up to end 2030	Up to end 2035	Up to end 2040	Up to end 2045	Up to end 2050
	Preferred plan	0.33	0.95	1.26	1.30	1.37
AP1	Switch to the core pathway in 2030	0.33	0.77	1.03	1.08	1.14

Notes

1. For completeness, the costs above include a total of £16m (across all pathways) for a package of investments to protect our sewage treatment works from flooding. We have not undertaken adaptive planning on this package as the impacts of future scenarios on river flooding requires further work. We will explore this in cycle 2.
2. Costs are presented cumulatively at a 2020/21 price base. The costs reflect those presented in the Ofwat data tables, noting that for the data tables, costs are presented per planning period and are split between addressing sewage treatment works compliance risks and protecting our sewage treatment works from flooding.

Table 0-3 Cumulative cost of the alternative pathway (addressing sewage treatment works compliance risks) (£bn)

We consider our preferred plan pathway to be the most likely assessment of future uncertainties, based on the information that has driven our current forecasts. We have devised alternative pathways to ensure that our ambition can be met across the range of plausible futures, as our planning forecasts may change in the future. Our ability to switch to the core pathway, through the alternative pathways we have defined, avoids the risk of undertaking investments in the short to medium-term that are not aligned with the forecasts that materialise in the long-term.

Adaptable solutions

Our final preferred plan comprises a range of different types of solutions of different sizes, dispersed across our catchments.

This provides the basis for developing an adaptive response to a range of different futures. Our approach is flexible, comprising network solutions such as multiple small to medium surface water management solutions that can be scaled up or down, or delivered sooner or later, in response to differing growth and climate change patterns. It is also focussed on interventions that allow us to better understand surface water interaction and how we can best manage that by working in collaboration with others to deliver better environmental and wellbeing benefits. In the case of treatment solutions, these can be implemented depending on changing futures.

Adaptive planning at a catchment level

At a catchment level, we have developed long-term adaptive plans for wastewater treatment up to 2100 for our Beckton and Mogden STW catchments. The adaptive pathway approach has considered core and alternative pathways in response to existing and emerging technology and innovation; asset renewal schemes; commercial opportunities in waste recovery; and synergies with our water resource management plan, to mitigate the risk that short-term decision making will reduce or jeopardise future choices.

Summary

As a result of applying an adaptive planning framework to our plan we consider that the key features that make the overall £33.3bn investment, with £1.5bn between 2025 and 2030, adaptable to different futures are:

- Our plan is based on the most likely growth and climate change forecasts in the near term
- Modular design of sewage treatment works upgrades and the small to medium, dispersed nature of network solutions (with surface water management being considered first) make the plan easy to change tack. There is no reliance on single locality, large infrastructure solutions that risk being stranded assets if forecast don't materialise
- Regular monitoring using leading (e.g., system capacity) and lagging measures (e.g., system performance) will ensure we can change the plan at the most appropriate point in time

Further work

We recognise that our DWMP adaptive pathway planning will mature over further cycles and our focus going forward will be on:

- Developing a programme of monitoring and modelling of surface water volumes and connections to our systems so that we can focus measures on surface water removal and, where appropriate, refine planned investments in our networks
- Establishing the importance of technology and innovation, such as smart networks, in informing our deliverability and pace of delivery of surface water management solutions. In addition, allowing time to explore technology and innovation improvements to maximise carbon efficiency when implementing our plan
- Continuing to map current and emerging innovation in treatment technologies for STW enhancements to provide resilience to technology change
- Ensuring option flexibility, allowing us to scale interventions up or down as we learn more about the risks and uncertainties in our plan

The next cycle of DWMPs will also benefit from the further information that will be gathered to enable us to better understand the impact of storm overflows on the environment.

By monitoring system performance over the plan period and re-evaluating our forecasts for climate change and growth, we can reappraise our alternative pathways throughout subsequent cycles of our DWMP and deliver our solutions in an adaptive and phased approach.

1 Our Drainage and Wastewater Management Plan (DWMP)

Our DWMP vision

1.1 Working in partnership to co-create a 25-year plan for drainage and wastewater that sustainably benefits communities and the natural environment in our region.

Our DWMP aim

1.2 To identify future catchment risks to our drainage and wastewater treatment systems and develop sustainable, efficient solutions to address them.

What we're trying to achieve

1.3 Protection of our environment, looking after the health of our rivers (aiming for zero harm from storm overflow discharges), being resilient to the risks of flooding and generating wider benefits to the communities we serve. DWMP outcomes for:

- Customers and communities – fair charges, improved health and wellbeing, increased amenity, and a resilient service
- Drainage and wastewater services – reduce sewer flooding and achieve 100% Sewage Treatment Works (STW) compliance
- The environment – increase biodiversity, zero harm from storm overflow discharges, environmental net gain

Description of the plan

1.4 A DWMP is a long-term costed plan that is focused on partnership working, which sets out the future risks and pressures for our drainage and wastewater systems. It identifies the actions that are required to make sure we can continue delivering our services reliably and sustainably, while also achieving positive outcomes for our customers, communities and environment.

1.5 Our long-term, collaborative plan aims to ensure a resilient and sustainable wastewater service for the next 25 years and beyond.

Framework

1.6 This is the first time we've produced a long-term plan for our wastewater business. Based on the national DWMP framework[5] that was developed jointly by regulators and industry bodies including Ofwat, Defra, the Environment Agency, Water UK, Welsh Government, Natural Resources Wales, Consumer Council for Water, Association of Directors of Environment, Economy, Planning and Transport and Blueprint for Water, the DWMP creates a roadmap for how we adapt our wastewater service to cope with future challenges.

[5] Working_Together_an_overview_of_Drainage_and_Wastewater_Management_Plans.pdf

Feedback on the public consultation on our draft plan

1.7 We undertook a formal public consultation of regulators, stakeholders and customers to collect feedback on our draft DWMP. We published our draft plan for public consultation on Thursday 30 June 2022. The consultation closed on Monday 26 September 2022. Alongside this we also undertook customer research using an online survey to collect additional feedback from our household (residential) and non-household (commercial) customers. Details of each part of our consultation are provided in Technical Appendix N - Consultation Response - You Said We Did.

1.8 The feedback from the public consultation, together with new legislation, has been used to inform our final DWMP. The consultation response showed general support for our draft preferred plan with more than 60% of our customers agreeing that our plan was acceptable.

1.9 Within the consultation responses, you said an adaptive planning approach should be applied to all areas of the plan as at draft our focus was on large London treatment sites. Also, you said we must use Ofwat's common reference scenarios as defined in the Long-Term Delivery Strategy guidance[6]. Further testing should be completed, considering common reference scenarios to evidence how the plan will adapt to future influencing factors like climate change. Our regulators also asked for more detail around how improved monitoring, including EDM and continuous water quality of outfalls, will inform adaptive pathways.

1.10 This document details how we applied the adaptive planning approach all areas of our plan, in alignment with Ofwat's guidance on long-term delivery strategies for PR24 (2022)[6] (summarised as Ofwat's LTDS guidance, in subsequent sections). Within Section 5 we discuss how improved monitoring will inform whether, in the future, we need to switch to alternative adaptive pathways, or stay on our preferred plan pathway.

[6] PR24 and beyond: Final guidance on long-term delivery strategies - Ofwat

2 Adaptive planning at the heart of our DWMP and LTDS

Progress

2.1 Adaptive planning is integral to our approach to developing our DWMP and aligned to Ofwat's LTDS guidance. Figure 2-1 is a process diagram that shows how adaptive planning links to preceding DWMP development stages (and contains hyperlinks to the technical appendices that describe each of them).

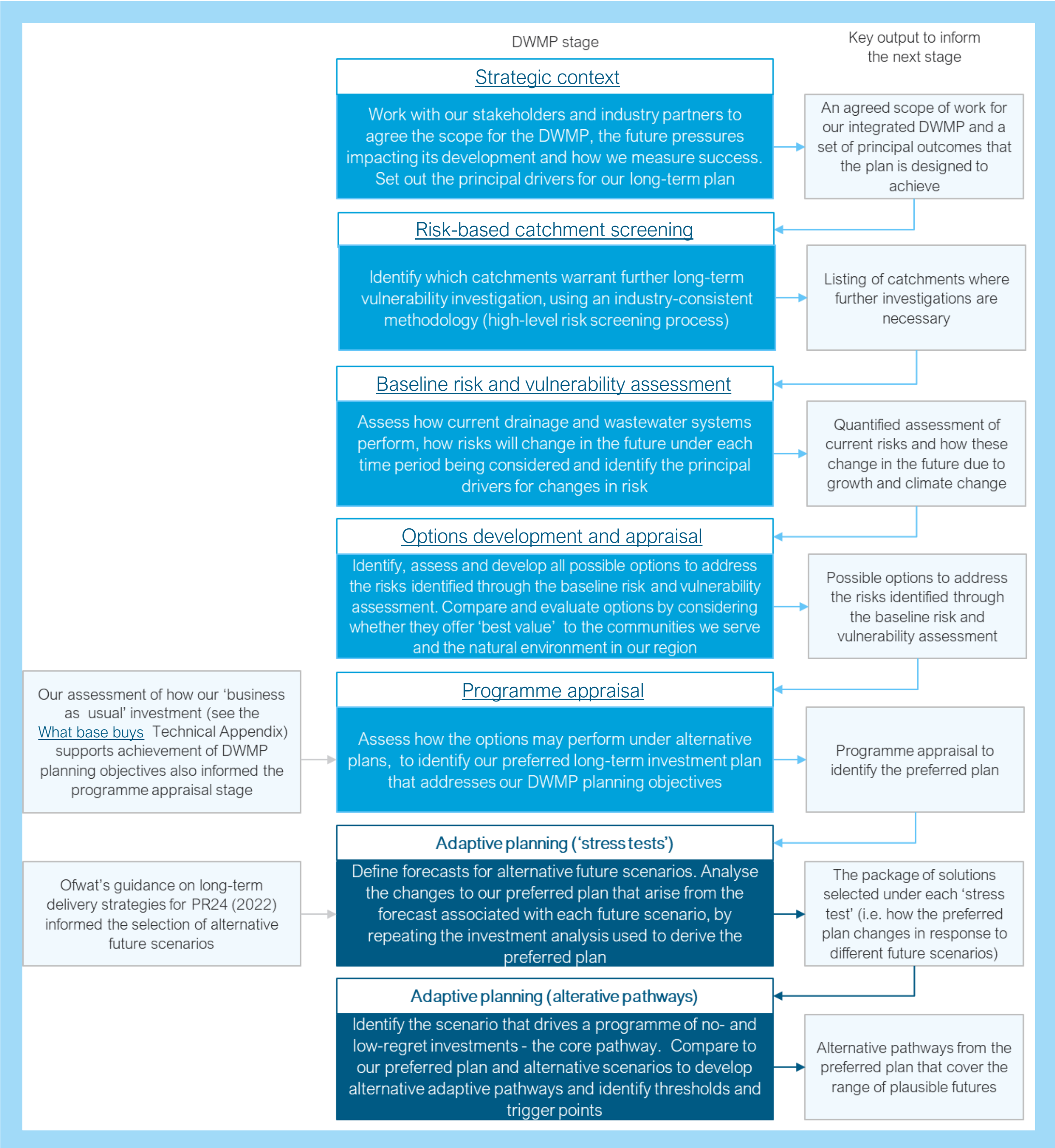


Figure 2-1 Process diagram showing how adaptive planning is integrated into our approach to developing our DWMP

3 What is adaptive planning and why do we need it?

Progress

3.1 Adaptive planning provides a framework for considering the range of future drivers and risks to plans and strategies, and future uncertainties in assessing these. Focus is given to the timing and scale of potentially significant drivers of uncertainty (such a climate change and population growth) that may lead to a range of alternative packages of investments to manage this future uncertainty. The process is iterative and may identify alternative options where uncertainty is significant, or a combination of options where the scale of need may increase in the future.

3.2 Adaptive planning helps explore how a strategy may be sensitive to alternative scenarios, risks and uncertainties, and provides greater transparency and supports engagement in decision making associated with developing a strategy. It helps focus decisions on no- or low-regrets options that would be justified under all plausible futures and in doing so, can be more cost efficient and deliver wider benefits over the longer-term.

3.3 Adaptive planning also helps identify (and subsequently avoid) potential pathways that may lead to abortive costs or maladaptation – where development of certain types of options are not future-proofed or fail to provide flexibility and resilience to alternative future scenarios. For example, advances in technology leading to treatment intensification meaning additional infrastructure is not required.

3.4 Under the adaptive planning approach, alternative pathways help identify how investment decisions may change in response to future scenarios. These pathways contain clear decision points which indicate when a judgement needs to be taken on an alternative pathway to efficiently deliver long-term outcomes. At these decision points, pathways deviate from each other due to different sets, or enhanced combinations of solutions, being required to manage the risks. The adaptation responses will be informed by pre-defined thresholds and trigger points, which identify the conditions that would cause one pathway to be adopted over another, using clear and observable metrics with an associated monitoring plan.

3.5 A world leading example of a live adaptive plan in action is that for the Thames Estuary 2100[7]. The strategy is to protect London from sea level rise to the year 2100. The potential options range from raising defences, over-rotating the existing barrier, flood storage, to a new barrier. Sea level is the metric to be monitored, with set water level rises being the trigger points determining decision points (see Figure 3-1).

[7] The Use of Adaptation Pathways in the Thames Estuary 2100 Plan; Evidence to support an adaptive approach to flood and coastal risk management (publishing.service.gov.uk)

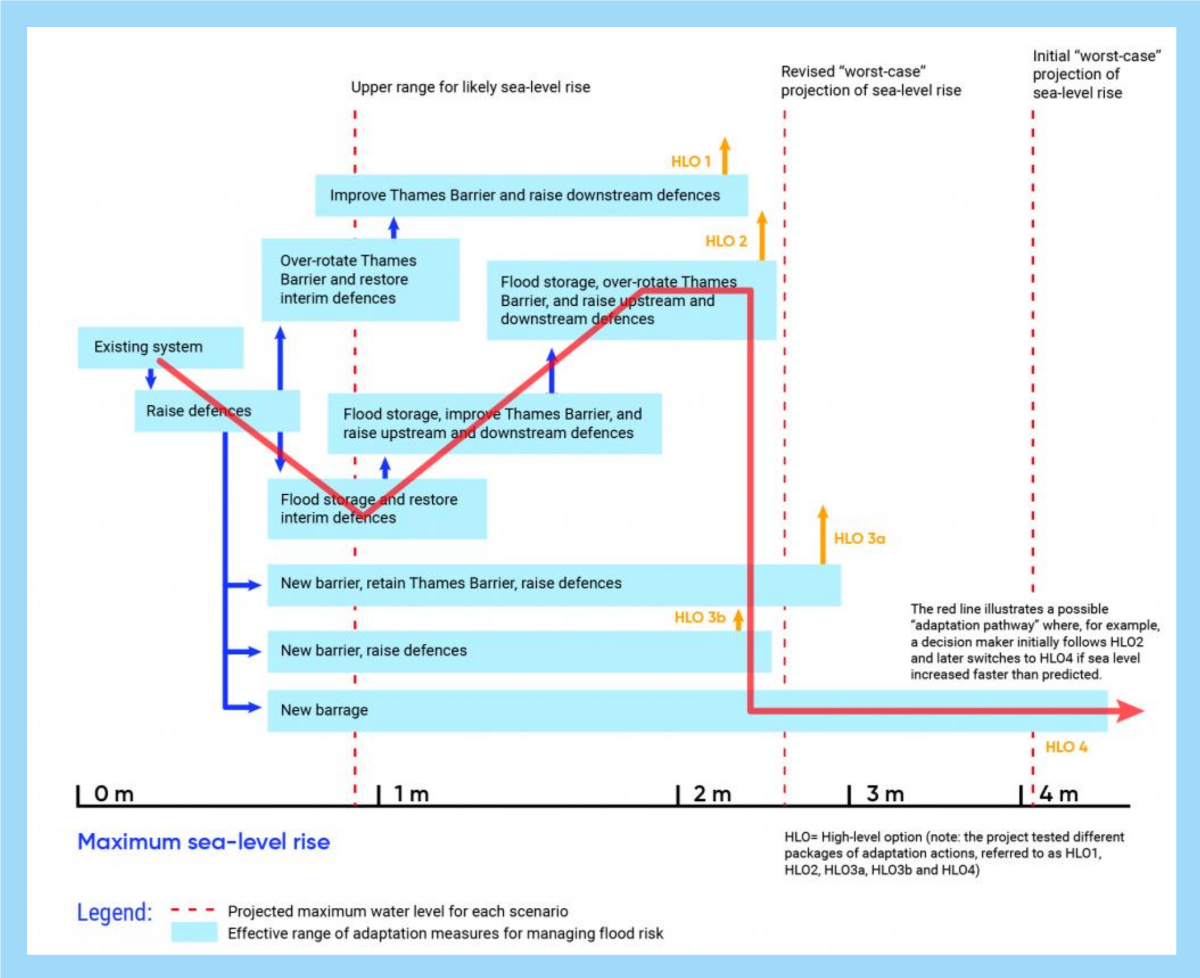


Figure 3-1 Thames Barrier adaptive plan

3.6 Adaptive pathways provide clarity on the decisions that may need to be taken to address future uncertainties, and agility/flexibility to the latest data; for example, climate science, population growth, or understanding and innovation in the range and type of options that may be deployed. This avoids the risk of being 'locked-in' to specific and inflexible solutions and helps communicate and make more timely decisions on investment.

3.7 Our approach to adaptive pathway planning has considered:

- A range of plausible futures
- A broad range of feasible solutions that could be deployed to meet the future scenarios defined
- Thresholds and trigger points that determine alternative decisions or pathways
- Historic performance, asset condition and trends that may indicate whether a service or asset is close to exceeding a threshold
- A framework for monitoring against those thresholds and trigger points
- Those solutions that are common to all futures and which may form the core of the strategy formulation
- The range of alternative decision or pathways and the potential trade-offs and risks of investing in emerging options sooner or later

3.8 Adaptive planning is central to Ofwat's LTDS guidance. This sets out how long-term delivery strategies should:

- Demonstrate the need for enhancement, activities and pathways to deliver planned outcomes
- Use scenario planning and a best value framework to demonstrate how PR24 measures and the timing of investments are appropriate to an uncertain future
- Prioritise no- or low-regret activities, demonstrating the benefits of planned investment against future uncertainties and risks; and where decisions have been taken to defer investment until the benefits are more certain

3.9 A glossary of key terms used in the document, when describing our adaptive planning approach, are provided in the following table. A glossary is also provided at the end of this document, detailing common terms used throughout our DWMP documents.

Term	Description
Adaptive pathway	A package of planned investments over time that can be adapted if future circumstances are different, when compared to those we had originally planned for. Adaptive pathways are specific to each individual plan, i.e., an alternative plan will have a different set of adaptive pathways.
Preferred plan	A package of planned investments over time, that we have selected as offering the best value to meet our DWMP ambition, based on the information currently available.
Core adaptive pathway	A package of no- and low-regret investments, including investment required to keep future options open. This helps to understand what activities should be undertaken regardless of circumstances.
Alternative adaptive pathway (or simply, alternative pathway)	A package of investments that should be undertaken only under certain circumstances. These circumstances are described by a trigger point.
Trigger point	The circumstances in which an alternative adaptive pathway would need to be followed.
Decision point:	The point in time when a decision would need to be taken about whether an alternative adaptive pathway is followed. This is either set at the same point in time as the trigger point, or in advance.
Scenario	A description of the future.
Plausible scenario	A scenario that is possible, but not necessarily the most likely.
Benign (or low) scenario:	A scenario that describes a less demanding change in a material factor than expected. Meeting long-term objectives under this scenario may involve lower investment than under an adverse scenario.
Adverse (or high) scenario	A scenario that describes a more demanding change in a material factor than expected. Meeting long-term objectives under this scenario may involve higher investment than under a benign scenario.
Common reference scenarios	A set of benign and adverse scenarios covering four material drivers of uncertainty (climate change, technology, demand and abstraction reductions), as detailed in Ofwat's LTDS guidance, against which we have tested our preferred plan.

Note
Descriptions taken from PR24 and beyond: Final guidance on long-term delivery strategies - Ofwat, with minor modifications.

Table 3-1 Glossary of key adaptive planning terms

4 Testing different future scenarios and their impact on our preferred plan

Progress

4.1 We have tested our preferred plan against different future scenarios, to understand how (and when) we would need to change our plan if future circumstances are different, when compared to those we have planned for as part of our cycle 1 DWMP.

4.2 The process we have followed is shown in Figure 4-1. This also highlights the sub-sections within sections 4 and 5 where each process step is described:

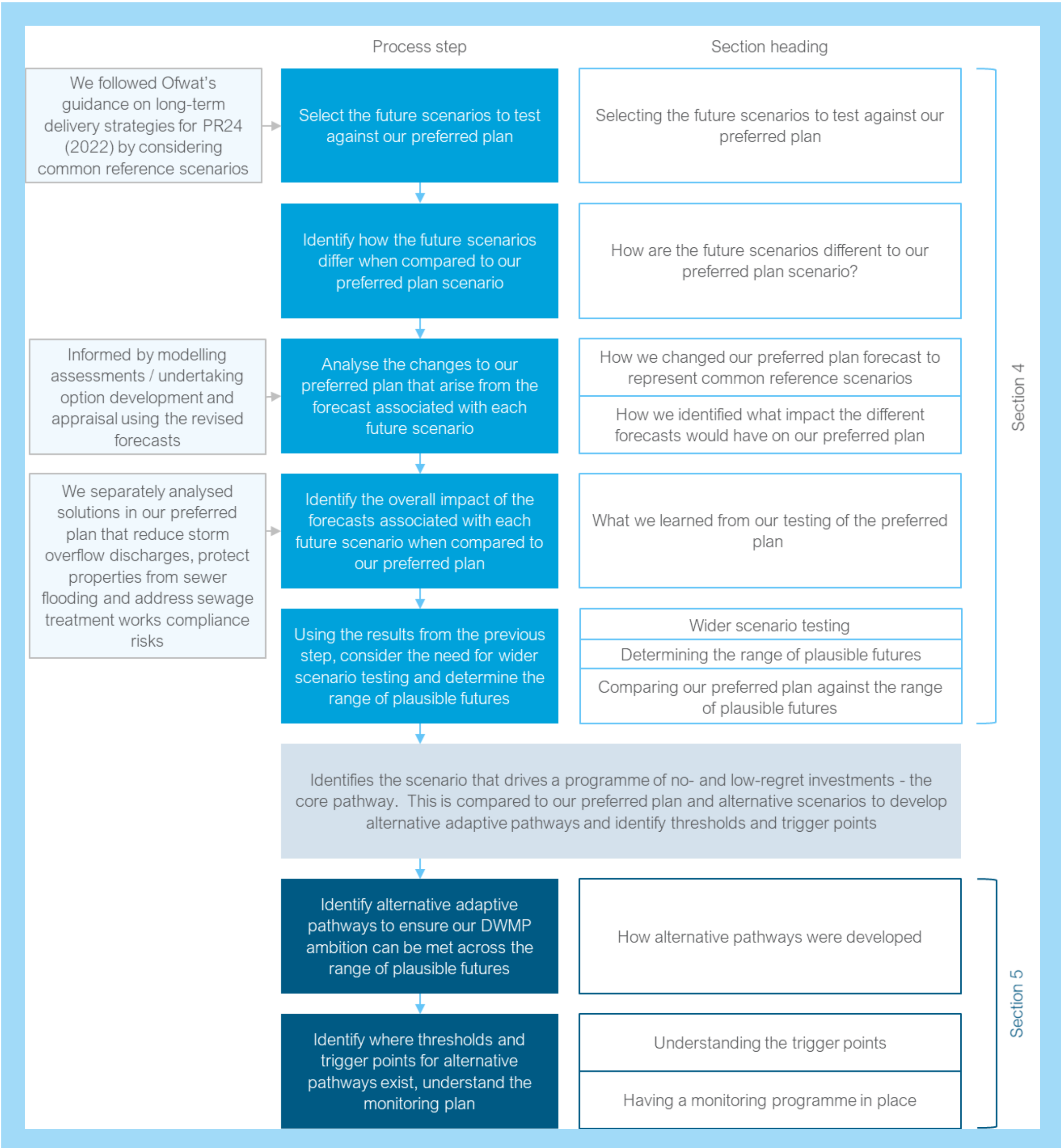


Figure 4-1 Process diagram showing how we tested future scenarios against our preferred plan

4.3 This process flow is aligned to the structure from Ofwat's LTDS guidance. The LTDS was produced towards the end of DWMP development for cycle 1 and where there are differences this is not in the process flow, but in the detail of forecast scenarios. This is explained in later sections.

4.4 Figure 4-2 illustrates how the outputs from the process steps described in section 4 link to the process step described in section 5.

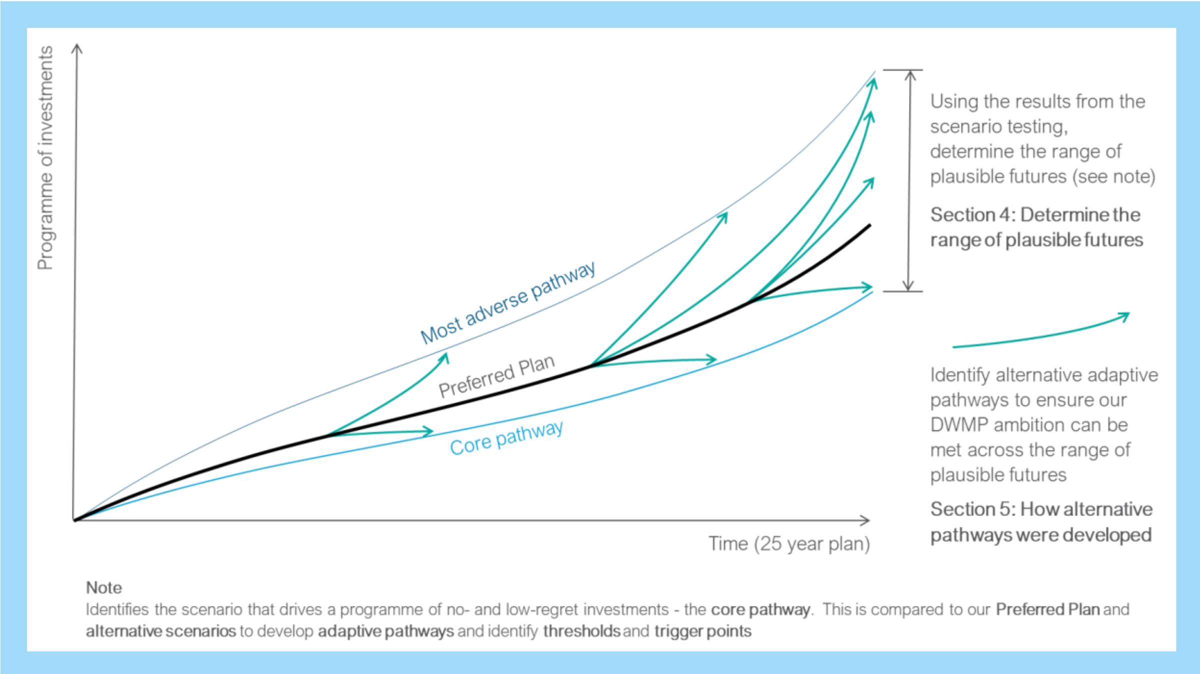


Figure 4-2 Illustration of how alternative pathways are derived from the most adverse, preferred and core pathways

4.5 Different parts of our preferred plan will respond differently to the future scenarios. To understand these differences in more detail, we separately analysed the following parts, or 'components', of our preferred plan:

- Reducing storm overflow discharges
- Protecting properties from sewer flooding
- Addressing sewage treatment works compliance risks

4.6 Each component represents a different outcome. To undertake the testing of our preferred plan against the common reference scenarios, we grouped our solutions into the above components[8].

4.7 As a precursor to this work, at draft DWMP stage we produced at an asset level, long term adaptive plans for wastewater treatment up to 2100 for our Beckton and Mogden STW catchments. This is detailed in Appendix A - Example adaptive pathways for our major sewage treatment works in London. We have incorporated our learning from this work into our plan level framework. This Technical Appendix mostly focuses on adaptive planning at a plan level.

[8] The investment profiles and trigger points associated with our adaptive pathways form one of a set of three data tables that we have produced (and published to support our DWMP) in accordance with Ofwat's requirements. Separating out the plan into its component parts is also driven by Ofwat's data structure requirements for DWMP Data Table 3 ('adaptive plans').

Selecting the future scenarios to test against our preferred plan

4.8 We followed Ofwat's LTDS guidance by considering 'common reference scenarios' to test against our preferred plan. This approach is being used by all water companies for the first cycle of DWMPs. As described in the Glossary (see Table 3-1), the common reference scenarios are a set of benign and adverse scenarios covering four material drivers of uncertainty (climate change, technology, demand and abstraction reductions).

4.9 Figure 4-3 highlights the common reference scenarios we selected for testing and provides the reasons why others were not selected. In total, we tested six of the eight common reference scenarios.

	Climate Change	Demand	Technology	Abstraction reductions
Adverse scenarios	High global emissions ✓	Higher growth forecasts ✓	Slower than expected technological improvements ✓	'Enhanced' scenario ✗
Benign scenarios	Low global emissions ✓	Lower growth forecasts ✓	Faster than expected technological improvements ✓	Current legal requirements ✗

Notes
1. We tested the climate change scenarios against our solutions that reduce the number of storm overflow discharges and protect properties from sewer flooding risk. Solutions that address sewage treatment works compliance risks were not tested against differing climate change scenarios. Assessment of the impact of climate change on sewage treatment works would require consideration of associated regulatory changes to permitting requirements (e.g., particularly in response to low flows in receiving waters), which is deemed outside the scope of the DWMP. Also, temperature changes may have a significant impact on our sewage treatment works processes. Research into potential impacts is needed to enable us to assess scenarios within our planning framework. Therefore, further consideration of climate change scenarios and their impact on our sewage treatment works has been deferred to cycle 2.
2. We did not test our preferred plan against differing scenarios relating to changes in the amount of water we abstract from rivers (to help manage our clean water supply needs).

   The enhanced scenario, as developed under the Environment Agency's National Framework sees greater environmental protection for Protected Areas, Sites of Special Scientific Interest (SSSI) rivers and wetlands, principal salmon and chalk rivers. In these water bodies the enhanced scenario applies the most sensitive flow constraint appropriate, increasing the proportion of natural flow that is protected for the environment.[9]

   For sewage treatment works, the impact on our solutions will be a function of whether the changes are permanent or temporary (for example, in response to a weather event). Permanent changes could lead to effluent discharge quality for downstream works to be re-evaluated by the Environment Agency with resulting requirements for treatment permits to be updated to reflect the changes. Temporary changes are difficult to predict and by their nature potentially short-term. For DWMP cycle 1 we have not modelled the impact of tighter permits at sewage treatment works; further consideration of different abstractions scenarios has been deferred to cycle 2.

   Abstraction reductions were deemed to have a negligible impact on our solutions that reduce the number of storm overflow discharges and alleviate risk of sewer flooding of properties. In the exceptional instances where there could be an impact (e.g., further tightening of specific overflow permits in response to low flows in receiving waters), comments as above for sewage treatment works are applicable.

Figure 4-3 Common reference scenarios tested against the preferred plan

4.10 Considering the definition of the technology scenario from the Ofwat LTDS guidance, the one aspect that has a material impact on the solutions in our preferred plan is for full smart

[9] Document template: green report (environment-agency.gov.uk)

water meter penetration by 2035, as opposed to 2045. This will create different scenarios for wastewater that is generated from the properties served by our sewer network (as the installation of a smart water meter is likely to change water usage, which in turn changes the amount of wastewater that drains to our sewer network).

4.11 Some technological innovations will improve performance but will not impact on the risks that our DWMP solutions are addressing. For example, installing more sensors in our sewer network will allow us to find and clear blockages before they cause flooding and/or harm to the environment, but this will not help to manage flows into our network or increase hydraulic capacity where required.

4.12 Other technological innovations will improve performance but are currently insufficiently developed to solve the scale of the issues that our DWMP solutions are addressing. Smart networks offer potential to increase capacity but only in certain types of catchments and locations.

4.13 We have an extensive smart network roll-out planned for the near-term including pilot installations to understand how to maximise the benefits of new technology. Further investment will be needed to install automated controls and develop 'digital twins' of our smart networks. These digital representations will identify how to optimise performance over a range of conditions, allowing us to actively manage networks (e.g., change their configuration) in real-time to maximise capacity. This will inform future DWMP cycles, providing a greater understanding of the costs and benefits of smart networks, enabling us to fully incorporate these types of solutions within our planning framework.

4.14 In future DWMP cycles, we expect that smart networks will also inform our deliverability and pace of delivery of surface water management solutions.

How are the future scenarios different to our preferred plan scenario?

4.15 The DWMP framework required that the plan was developed using forecasts set and published in December 2020. Other forecasts have subsequently been published (within Ofwat's LTDS guidance). Between draft and final we have adjusted our preferred plan to account for this and to minimise any miss-alignment of forecasts between different components of the plan (reducing storm overflow discharges, protecting properties from sewer flooding, addressing sewage treatment works compliance risks).

4.16 We compared the detailed descriptions of each common reference scenario (as stated in Ofwat's LTDS guidance) with the forecast we made when devising our preferred plan[10], to understand the differences between them.

4.17 Figure 4-4 shows our preferred plan forecast in relation to the range between each high (adverse) and low (benign) scenario, for the common reference scenarios we tested.

[10] Our forecasts we derived during the Baseline Risk and Vulnerability Assessment stage of the DWMP, which was completed in 2020. This was prior to the publication of Ofwat's LTDS guidance in April 2022.

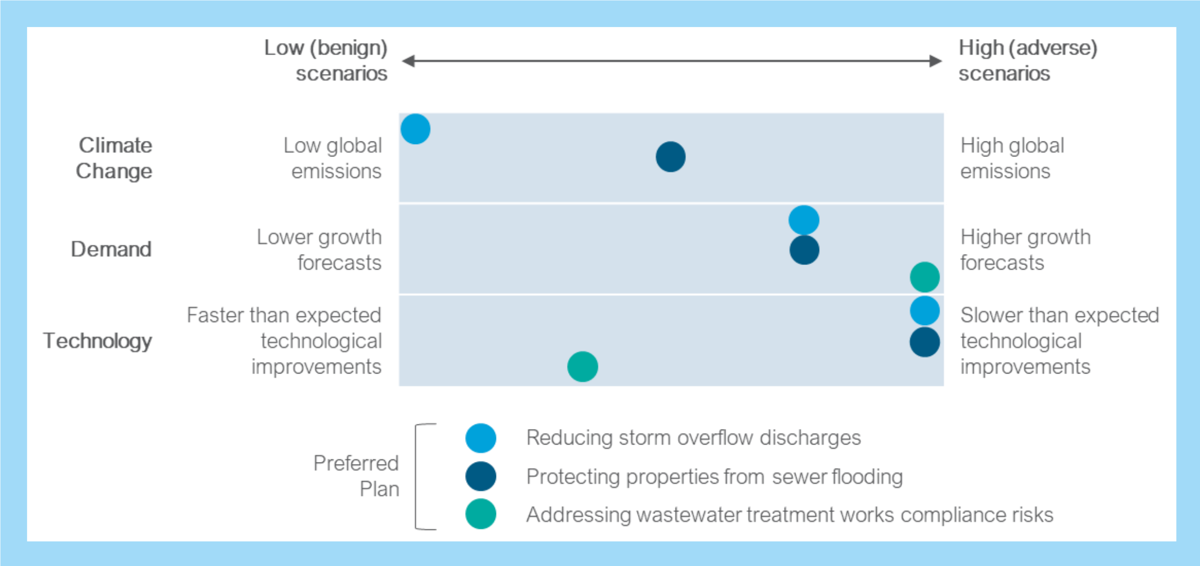


Figure 4-4 How our preferred plan forecast compares to the common reference scenarios

4.18 When considering climate change, solutions in our preferred plan that reduce storm overflow discharges are based on a forecast representative of a low common reference scenario (low global emissions). Solutions that protect properties from sewer flooding are based on a forecast that represents the mid-point between a high and low scenario.

4.19 These positions have arisen due to recent advances in the forecasting of future rainfall patterns and storms, in responses to the latest climate change science. This has occurred over the timescale in which we have produced our DWMP (see Table 4-1).

4.20 When considering the demand and technology common reference scenarios, our Baseline Risk and Vulnerability Assessment and preferred plan align with the high scenarios set out in the Ofwat LTDS guidance.

4.21 Exceptions to the above are:

- Our demand forecasts for solutions that reduce storm overflow discharges and protecting properties from flooding, which are closer to the high scenario than the low
- Our technology forecasts for solutions that address sewage treatment works compliance risks, which are closer to the low scenario than the high

How we changed our preferred plan forecast to represent common reference scenarios

4.22 We then changed our preferred plan forecast to represent each of the common reference scenarios to be tested. The changes we made to our forecasts are shown in Table 4-1.

How we identified what impact the different forecasts would have on our preferred plan

4.23 Using the amended forecasts, we repeated elements of our Options Development and Appraisal to understand how our preferred plan would change, in terms of:

- Impact on the cost and scale of the solutions in our preferred plan, and/or
- Whether different solutions would be needed

4.24 Our approach is shown in Table 4-2.

Common reference scenario		Reducing storm overflow discharges	Protecting properties from sewer flooding	Addressing sewage treatment works compliance risks
Climate change	Adverse	Latest climate change tools used to create annual rainfall representative of a high global emissions scenario (see note 1)	2050 rainfall intensity uplift increased to 20% compared to our preferred plan forecast of 15% (see note 2)	
	Benign	Our preferred plan is representative of a benign (low) scenario; no changes required	2050 rainfall intensity uplift decreased to 8% compared to our preferred plan forecast of 15% (see note 2)	
Demand	Adverse & Benign	We separately assessed every catchment against Local Plan and Office for National Statistics forecasts, to create a new adverse (high) or benign (low) forecast, depending on which forecast was used in our preferred plan (see note 3)		
Technology	Adverse & Benign	We compared the forecasts in our preferred plan (for wastewater generated by the population our networks serve), for a large sample of catchments, against forecasts representative of the definitions for adverse and benign scenarios in the Ofwat LTDS guidance (arising from variation in the extent of smart water meters installed in properties). From this analysis, we created a new adverse (high) or benign (low) forecast for all catchments, depending on which forecast was used in our preferred plan.		We reviewed all sites with investment identified in our preferred plan alongside those indicated in the BRAVA as being at 90% of their Dry Weather Flow (DWF) permit in 2050. We compared the basis of the flow assessment, in relation to return to sewer (RTS) flows, against low (benign) and high (adverse) (see note 4).

Notes

1. We revised our assessments of storm overflow discharge frequency and volume using an industry standard rainfall tool aligned to the latest climate change science[11] and representative of the Ofwat LTDS guidance for the adverse scenario. The tool has been updated since we undertook our original Baseline Risk and Vulnerability Assessments.
2 Similar to that described for 'reducing storm overflow discharges', we revised the design rainfall used to assess the risk of property sewer flooding using the latest industry guidance (again aligned to the latest climate change science)[12]. Our original Baseline Risk and Vulnerability Assessment was completed in December 2020 using the best current guidance at that time[13].

[11] Climate Change Rainfall for use in Sewerage Design - Design Storm Profiles, Antecedent Conditions, Red-Up Tool Update and Seasonality Impacts (ukwir.org)
[12] FUTURE_DRAINAGE_Guidance_for_applying_rainfall_uplifts.pdf (ceda.ac.uk)
[13] Rainfall Intensity for Sewer Design - Stage 2 (ukwir.org)

3. Demand (population growth) forecasts (as used in our Baseline Risk and Vulnerability Assessment, therefore representing forecasts made in 2020):

- Local Plan: the use of forecasts based on Local Plan data, as prepared by the Local Planning Authority
- Office of National Statistics: the use of forecasts derived by the Office of National Statistics, which are based on extrapolation of historical trends

When considering the preferred plan at a company-wide level, Local Plan forecasts provide a high (adverse) scenario, but when considering at a catchment level, the opposite may be true.

4. There is significant overlap with per capita consumption (PCC) reductions due to building regulations and product standards. and PCC reductions within the technology scenario. PCC reductions have been considered in the latter scenario only.
5. The flow received by our STWs is influenced by the amount of water supplied/used by our customers. To assess the impacts, convention assumes that 95% of water supplied is returned to our sewer network. RTS flows were taken as being 104.5 l/h/d and 114 l/h/d (per capita consumption 110 l/h/d and120 l/h/d) respectively[14].

Table 4-1 How we changed our preferred plan forecast to represent common reference scenarios

<table>
<tr><th colspan="2">Common reference scenario (see note 1)</th><th>Reducing storm overflow discharges</th><th>Protecting properties from sewer flooding</th><th>Addressing sewage treatment works compliance risks</th></tr>
<tr><td rowspan="2">Climate change</td><td>Adverse</td><td>We repeated our ODA work on a sample of storm overflows and identified an average cost uplift to apply to all storm overflow solutions</td><td rowspan="2">We repeated our ODA work on a sample of catchments and identified an average cost increase or decrease to apply to all catchment property flooding solutions.</td><td rowspan="2"></td></tr>
<tr><td>Benign</td><td>Preferred plan representative of a benign (low) scenario; impact assessment not required</td></tr>
<tr><td>Demand</td><td>Adverse & Benign</td><td>For most of the solutions in our preferred plan, our option development work had identified the investment needed to offset future changes from the current position, to 2050. We adjusted this ‘future-proofing’ phase of investment based on the change in demand (as described in Table 4-1). We used this analysis to subsequently revise</td><td>We repeated our ODA work on a sample of catchments and derived a relationship between the increase or decrease in demand and the associated change in investment. The relationship was applied to the solutions (using revised forecasts as described in Table</td><td>Preferred solution costs are based on a cost model with population as the primary yardstick. We used the ratio of preferred plan residential population to high/low scenario values to provide an adjustment factor that was used to derive a revised cost.</td></tr>
</table>

[14] Meeting our future water needs: a national framework for water resources - GOV.UK (www.gov.uk)

Common reference scenario (see note 1)		Reducing storm overflow discharges	Protecting properties from sewer flooding	Addressing sewage treatment works compliance risks
		solutions that had not been split into phases.	4-1), to derive a revised cost.	
Technology	Adverse & Benign	The impact on storm overflow performance, when considering variation in the amount of wastewater generated by the population our networks serve (due to variation in the extent of smart water meters installed in properties) and population change (as assessed in Demand), is similar (see note 2). Therefore, the cost / change in population relationship from the Demand scenario assessment was used when assessing the impact of a faster or slower rate of reduction (over time) in the amount of wastewater generated by the population our networks serve.	A similar approach as described for 'reducing storm overflow discharges' was taken to assess the impact of the revised forecasts associated with this scenario.	We calculated the scenario impact on the percentage of DWF permit utilised. Where the risk had changed, and a scheme was proposed, we used the ratio of percentage of permit utilised to derive a factor that was used to adjust costs. Where a new risk was identified (not included in the preferred plan) we used a cost curve, derived from existing solutions, to output a cost for the new solution.

Notes
1. When undertaking our assessments, we considered each common reference scenario separately, in accordance with Ofwat's LTDS guidance.
2. For example, a 10% reduction in the amount of wastewater generated by the population served by our network upstream of an overflow would have the same impact as a 10% reduction in the population upstream.
3. The change in cost informed our assessments of the required changes in the scale of solutions in our preferred plan, and whether different solutions would be needed.

Table 4-2 How we identified the impact different forecasts would have on our preferred plan

What we learned from our testing of the preferred plan

4.25 The diagrams below detail the change in the cost of each component when comparing our preferred plan to each common reference scenario we tested it against.

Note
All stated costs in this Technical Appendix include both construction and operating costs. Costs are presented at a 2020/21 price base, which aligns with costs submitted in the Ofwat data tables. Costs are subject to rounding; however, totals are correct.

Figure 4-5 Comparing our preferred plan to the scenarios we tested (change in cost)

4.26 The adverse climate change scenario has the most significant impact on our solutions for reducing storm overflow discharges (a 29% increase). Our preferred plan represents a benign climate change scenario (see Figure 4-4). The testing of the adverse scenario identified a cost increase of 33% (to 2050) due to the significant rainfall uplifts applied, when compared to the benign scenario. The overall result is a 29% increase, as some of our preferred plan (benign scenario) short term investments are already 'future-proofed' and do not require an increase in the adverse scenario.

4.27 When considering our solutions for protecting properties from sewer flooding, our preferred plan is in the middle of the benign/adverse range (plus or minus 6%). Climate change has a smaller impact on sewer flooding proposals, as the variation between benign/adverse scenarios is lower for the rainfall we model when testing property sewer flooding solutions, compared to the rainfall we model when testing storm overflow discharge solutions[15].

4.28 For both components, demand and technology scenarios show a significantly lower impact compared to climate change scenarios. This is because the timing and scale of solutions in our preferred plan is driven primarily by future flood volumes (due to hydraulic overload of our sewer network) and storm overflow discharge volumes. Both of these will be significantly impacted by rainfall under future climate change scenarios. This significantly outweighs the potential impact of future demand and technology scenarios on wastewater generated by our customers.

4.29 The current resident population served by our wastewater network is 15.5 million. This is forecast to reach 16 million in 2025. Between 2025 and 2050, the forecast increase in resident population in our region ranges from 0.5 million to 3 million, based on the benign and adverse demand scenarios.

4.30 The benign demand scenario has the most significant impact on the solutions required to address sewage treatment works compliance risks (a 17% decrease). This is because our preferred plan tracks the adverse demand scenario (see Figure 4-4). In contrast, because our preferred plan is in the middle of the benign/adverse range of our technology scenarios, a benign scenario outcome would have a significantly lower impact.

4.31 Table 4-3 shows the impact of these changes on the package of solutions within our preferred plan and the overall cost associated with reducing storm overflow discharges and protecting properties from sewer flooding.

4.32 As can be expected, the results show that the same or more investment is needed in all adverse scenarios, with lesser investment needed for benign scenarios. There are very minor differences across all scenarios, up to 2035. Between 2035 and 2040 there is variation in the required scale of solution types across the scenarios. Significant differences are seen from 2040 onwards, particularly for the adverse climate change scenario.

[15] Our target is to ensure properties are protected against sewer flooding in storms that have a 1 in 50 chance (2% probability) of being equalled or exceeded in any given year. When considering storm overflow discharges, the targets require consideration of storms with much higher probabilities as they relate to storms typically occurring every year.

4.33 The following key observations are made for each of the solution types presented in the table:

- Surface water management (hectares managed): there is limited variation when our preferred plan is compared to the pathways arising from the common reference scenarios. When devising our preferred plan, we have included what we consider to be the maximum achievable implementation of surface water management in London. Therefore, other solution types will increase in number and scale, for scenarios that require an increase when compared to our preferred plan. We have also prioritised surface water management over network improvements when considering any reductions (i.e., associated with benign pathways). Therefore, the limited variation arises from a change in the scale of our preferred plan in the Thames Valley and Home Counties planning area
- Network improvements (storage, 000s of m3): this solution type has significant increases for the climate change adverse scenario, largely associated with increases required to achieve our storm overflow discharge targets, as our preferred plan represents the benign scenario
- Network improvements (new sewers, km): noting there are constraints placed on other solution types (e.g., surface water management and sewer lining), and our package of investment to address storm overflow discharges is largely comprised of surface water management and network improvements by providing storage, variation in this solution type is largely associated with the package of investments to protect properties from sewer flooding, across the scenarios tested
- Storage at sewage treatment works (storage, 000's of m3): this solution type has significant increases for the climate change adverse scenario, associated with increases required to achieve our storm overflow discharge targets, noting that our preferred plan represents the benign scenario
- Sewer lining (km): when developing our sewer lining programme, we used a targeted approach to identify the sewers that are most impacted by groundwater. The package of investments was not altered as the demand and technology scenarios do not affect groundwater, although we expect technology to improve our understanding of the risk of groundwater flooding. Advances in technology, generating efficiencies when implementing our ambitious sewer lining programme, is assumed/implicit. Further work is required to understand and quantify the impact climate change may have on the rate at which groundwater is recharged (and the resulting impact on our networks). We will explore this in cycle 2. Besides addressing groundwater ingress into our network, our sewer lining programme will have a benefit where there is a risk of exfiltration from our networks to groundwater

4.34 Table 4-4 shows the impact of these changes on the overall cost associated with addressing sewage treatment works compliance risks. This highlights the significant impact of the adverse demand scenario, compared to other scenarios.

Preferred solution type	Unit	Planning horizon	Preferred plan	Climate change benign	Climate change adverse	Demand benign	Demand adverse	Tech benign	Tech adverse
Reducing storm overflow discharges									
Surface Water Management	Hectares managed	2025-2030	80	80	80	80	80	80	80
		2030-2035	20	20	20	20	20	20	20
		2035-2040	360	360	360	360	360	360	360
		2040-2045	190	190	190	190	190	190	190
		2045-2050	470	470	470	470	470	470	470
Network Improvements (storage)	000's of m3	2025-2030	5	5	5	5	5	5	5
		2030-2035	1,448	1,448	1,454	1,446	1,448	1,445	1,448
		2035-2040	1,574	1,574	1,734	1,554	1,584	1,545	1,574
		2040-2045	1,391	1,391	1,639	1,347	1,410	1,334	1,393
		2045-2050	311	311	1,511	240	323	216	311
Network Improvements (new sewers)	km	2035-2040	4	4	4	4	4	4	4
		2045-2050	10	10	48	8	10	7	10
Storage at STWs	000's of m3	2025-2030	22	22	22	22	22	22	22
		2030-2035	289	289	289	289	289	289	289
		2035-2040	481	481	526	475	484	473	481
		2040-2045	621	621	831	582	638	574	623
		2045-2050	15	15	74	12	16	11	15
Sewer Lining	km	All	661	661	661	661	661	661	661
Total cost	**£bn**		11.8	11.8	15.2	11.5	11.9	11.4	11.8
Protecting properties from sewer flooding									
		2025-2030	100	100	100	100	100	100	100

Preferred solution type	Unit	Planning horizon	Preferred plan	Climate change benign	Climate change adverse	Demand benign	Demand adverse	Tech benign	Tech adverse
Surface Water Management	Hectares managed	2030-2035	50	40	50	50	50	50	50
		2035-2040	610	600	620	610	610	610	610
		2040-2045	2,440	2,430	2,440	2,430	2,440	2,430	2,440
		2045-2050	3,270	3,240	3,310	3,270	3,270	3,270	3,270
Network Improvements (storage)	000's of m3	2030-2035	13	6	19	12	13	12	13
		2035-2040	145	114	174	141	146	140	146
		2040-2045	633	569	690	624	634	623	633
		2045-2050	1,124	1,017	1,233	1,110	1,125	1,107	1,125
Network Improvements (new sewers)	Km	2025-2030	53	53	53	53	53	53	53
		2030-2035	2	2	3	2	2	2	2
		2035-2040	15	4	30	13	15	11	15
		2040-2045	229	197	264	223	231	219	229
		2045-2050	674	614	743	663	678	656	674
Sewer Lining	Km	All	1,190	1,190	1,190	1,190	1,190	1,190	1,190
Total cost	£bn		20.2	19.0	21.4	20.0	20.2	19.9	20.2

Reducing storm overflow discharges and Protecting properties from sewer flooding

Surface Water Management	Hectares managed	2025-2030	180	180	180	180	180	180	180
		2030-2035	70	60	70	70	70	70	70
		2035-2040	970	960	980	970	970	970	970
		2040-2045	2,630	2,620	2,630	2,620	2,630	2,620	2,630
		2045-2050	3,740	3,710	3,780	3,740	3,740	3,740	3,740

Preferred solution type	Unit	Planning horizon	Preferred plan	Climate change benign	Climate change adverse	Demand benign	Demand adverse	Tech benign	Tech adverse
Network Improvements (storage)	000's of m3	2025-2030	5	5	5	5	5	5	5
		2030-2035	1,461	1,454	1,473	1,458	1,461	1,457	1,461
		2035-2040	1,719	1,688	1,908	1,695	1,730	1,685	1,720
		2040-2045	2,024	1,960	2,329	1,971	2,044	1,957	2,026
		2045-2050	1,435	1,328	2,744	1,350	1,448	1,323	1,436
Network Improvements (new sewers)	Km	2025-2030	53	53	53	53	53	53	53
		2030-2035	2	2	3	2	2	2	2
		2035-2040	19	8	34	17	19	15	19
		2040-2045	229	197	264	223	231	219	229
		2045-2050	684	624	791	671	688	663	684
Storage at STWs	000's of m3	2025-2030	22	22	22	22	22	22	22
		2030-2035	289	289	289	289	289	289	289
		2035-2040	481	481	526	475	484	473	481
		2040-2045	621	621	831	582	638	574	623
		2045-2050	15	15	74	12	16	11	15
Sewer Lining	Km	All	1,851	1,851	1,851	1,851	1,851	1,851	1,851
Enhancing our modelling capabilities			Yes	Yes	Yes	Yes	Yes	Yes	Yes
Partnership working			Yes	Yes	Yes	Yes	Yes	Yes	Yes
Total cost	£bn		31.9	30.8	36.6	31.4	32.1	31.2	32.0

Key

Green: The scope (and cost) of solutions is the same or more than the preferred plan
Orange: The scope (and cost) of solutions is less than the preferred plan

Table 4-3 Comparing our preferred plan to the scenarios we tested (change in cost and package of solution types: reducing storm overflow discharges and protecting properties from sewer flooding)

Solution type	Description
Surface water management	Surface water separation and the installation of features to collect, store and/or infiltrate surface water from buildings and impermeable areas, such as driveways and carparks as part of enhancing our surface water sewerage system. This option also looks to reinforce the fundamental basis of our sewerage systems being separate by addressing property misconnections of surface water into the foul sewer network or foul to surface water.
Network improvements	Managing the impact of surface water on the sewerage system through the identification of network improvements to address deficiencies in the sewerage network capacity. This includes the construction of large attenuation sewers, new surface water and foul water sewers.
Sewer lining	Undertaking a programme of sewer lining (and manhole sealing). We'll target as a priority the areas of high infiltration risk that lead to unwanted flows in our sewerage systems and that currently take up valuable capacity.
Storage at STWs	Managing the impact of surface water on the sewerage system, by providing additional storage capacity at sewage treatment works, to reduce storm overflow discharges.

Note
Activity quantities for some solution types that have a significantly lower investment requirement compared to those presented are not presented in the tables (noting that total costs include for the package of investments for these solution types):

- Individual property level protection (providing vulnerable homes with active and passive sewer flood protection measures such as flood proof doors, self-sealing bath/shower systems (non-return valves) and installation of household pumping stations)
- Surface water management measures that use, for example, parks and open spaces to store surface water to reduce flood risk
- Screening of storm overflow discharges to reduce their visual impact on receiving waters, where screens are not currently installed

Table 4-3 Comparing our preferred plan to the scenarios we tested (change in cost and package of solution types: reducing storm overflow discharges and protecting properties from sewer flooding) (continued)

Preferred solution type	Unit	Planning horizon	Preferred plan	Demand benign	Demand adverse	Tech benign	Tech adverse
Treatment process technologies	£bn	2025-2030	0.33	0.33	0.33	0.33	0.33
		2030-2035	0.61	0.43	0.62	0.61	0.63
		2035-2040	0.30	0.25	0.30	0.29	0.31
		2040-2045	0.04	0.05	0.04	0.04	0.05
		2045-2050	0.07	0.06	0.07	0.06	0.07
		All	1.35	1.13	1.36	1.34	1.38
Protecting our sewage treatment works from river flooding (see note)	£bn	All	0.02	0.02	0.02	0.02	0.02
Total	£bn	All	1.37	1.14	1.37	1.36	1.40

Solution type	Description
Treatment process technologies	Implementation of a range of different technologies identified to enhance the performance of the STW, through either retrofitting or new-build options. This will include the use of more intensive wastewater treatment processes which have the capacity to meet future demands.
Protecting our sewage treatment works from river flooding	Implementation of measures such as the construction of bunds to protect our assets from high river levels

Note

For completeness, the costs above include a total of £16m (rounded to £0.02bn in the table, across all scenarios) for a package of investments to protect our sewage treatment works from river flooding. We have not undertaken adaptive planning on this package as the impacts of future scenarios on river flooding requires further work. We will explore this in cycle 2.

Table 4-4 Comparing our preferred plan to the scenarios we tested (change in cost: addressing sewage treatment works compliance risks) (£bn)

Adaptable solutions to accommodate future uncertainties

4.35 Our preferred plan comprises a range of different types of solutions of different sizes, dispersed across our catchments. This provides the basis for developing an adaptive response to a range of different futures.

4.36 Our approach is flexible, comprising network solutions such as sewer relining, as well as multiple small to medium surface water management solutions that can be scaled up or down, or delivered sooner or later, in response to differing growth and climate change patterns. It is also focussed on interventions that allow us to better understand surface water interaction, and how we can best manage that working in collaboration with others, to deliver environmental and wellbeing benefits. In the case of treatment solutions, these can be implemented depending on changing futures.

4.37 Our hierarchy of network solution types (and for all storm overflows, whether located in our networks or at our sewage treatment works) commences with surface water management in our London catchments. These provide the basis for the development of a strategy to support an adaptive response. Our approach allows us to flex the scale of the programme based on our developing understanding and innovation in the delivery of these schemes, as well as improving our understanding of future risks. This will support the development of an adaptive plan in future cycles, using catchment wide trigger points to identify system capacity changes.

4.38 The plan for our catchments outside of London targets the reduction of groundwater infiltration, inundation and surface water inputs to the wastewater system, as well as responding to demand. It then considers a mix of network improvement solutions alongside surface water management. Our approach provides the basis for an adaptive response by developing a greater understanding of those inputs and their impacts on our systems, and therefore, the solutions needed to address them.

4.39 Surface water management provides a range of benefits that can support an adaptive response:

- The design and development of surface water management solutions provides resilience to future climate change and growth
- The rate and amount of surface water we manage is flexible and can be changed in response to changing future risks
- Surface water management also provide an opportunity to enhance environmental resilience as well providing green infrastructure benefits to health and wellbeing
- Innovation in the design and delivery of surface water management alongside a better understanding of surface water interactions with our system will also inform the scale, pace and delivery capacity of these solutions

4.40 Our treatment solutions generally have a long asset life, but we have considered emerging technology such as Integrated Fixed Film Activated Sludge (IFAS) which provides a greater degree of flexibility to delivering additional biological capacity.

Wider scenario testing

4.41 The common reference scenarios are the key drivers of uncertainty that may impact on our plan. Compared to the scenarios we tested; other factors are either not likely to impact our plan as significantly or are likely to have similar impacts. For example, customer behaviours in relation to water consumption and return to sewer flows may change in the future, for reasons beyond our influence, which may place less demands on our networks and treatment works. However, we have considered demand changes within the common reference scenarios (due to changing population growth forecasts and technological advances lowering water consumption).

4.42 Therefore, even if we considered other factors, the range of uncertainty over which we need to develop an adaptive approach is likely to remain unchanged. For cycle 1 we have focussed on the common reference scenarios; during cycle 2 of our DWMP we will broaden the range of factors we consider, to confirm their impact (for example, to reflect factors such as deliverability, changing public opinions on environmental protection and affordability).

4.43 In our Risk and Uncertainty Technical Appendix we have explored how our strategy is resilient to a range of risks. This demonstrates our understanding of risks other than those raised by the common reference scenarios and how we have considered these risks in the development of our plan.

4.44 In the development of our preferred plan, we have also considered alternative plans that achieve different targets and have a different pace of delivery. This is detailed in our Programme Appraisal Technical Appendix.

Determining the range of plausible futures

4.45 Based on the results of our testing of the preferred plan against the common reference scenarios, we then determined a range of plausible futures. Our alternative pathways need to meet our DWMP ambition over this range.

4.46 In our assessment of all pathways arising from our testing (both benign and adverse), we included all activities that need to be undertaken to be ready for all plausible future scenarios, such as future monitoring requirements and improvements to our modelling capabilities. This is described in more detail in the subsequent sections titled ‘Understanding the trigger points’ and ‘Having a monitoring programme in place’.

4.47 For each preferred plan component, we assessed a plausible most adverse adaptive pathway.

4.48 We have also identified a ‘core adaptive pathway’; being the pathway that drives a programme of no- and low-regret investments, including investment in monitoring, investigations and other activities to ensure other options can be efficiently implemented should the need to switch pathways arise in the future. This is aligned to Ofwat’s LTDS guidance.

4.49 The core plan is not the same as a least cost plan (in the short term), as it includes some activities as stated in the previous paragraph which are not required to address our short-term targets but are required to keep future options open. If we do not prepare for plausible futures, our plan is likely to cost more in the long-term.

4.50 Each common reference scenario represents a ‘plausible extreme’. However, if combined, they would represent a very low probability scenario. Therefore, when assessing the range of plausible futures, we avoided combining high or low drivers of uncertainty. This aligns with Ofwat’s LTDS guidance. We determined the programme of investments to meet the most significant driver for change, then adjusted that programme to meet a ‘central forecast’ for other drivers (rather than high or low). This is shown diagrammatically in Figure 4-6.

4.51 The following bullet points describe how we assessed a plausible most adverse pathway and a core pathway for each preferred plan component:

Reducing storm overflow discharges and protecting properties from sewer flooding

- Most adverse: assessed using the adverse climate change scenario, adjusted to reflect a central forecast for the demand and technology scenarios
- Core: assessed from the benign climate change scenario, adjusted to reflect a central forecast for the demand and technology scenarios and also including investment in monitoring, investigations and other activities to ensure other options can be efficiently implemented should the need to switch pathways arise in the future

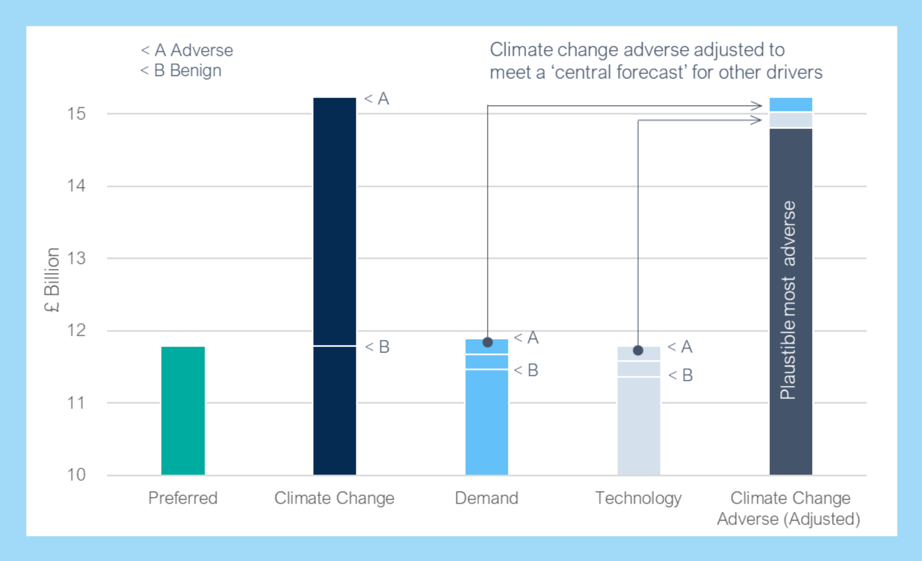


Figure 4-6 Example showing how we avoided combining high drivers of uncertainity (when assessing the overall cost of the plausible most adverse scenario for storm oveflow discharges)

Addressing sewage treatment works compliance risks

- Most adverse: assessed from the adverse demand scenario, adjusted to reflect a central forecast for the technology scenario
- Core: for most solutions in our preferred plan, the benign demand scenario generated the no and low-regret programme of investments, except for three sewage treatment works, where the benign technology scenario resulted in no/low-regret investment. Therefore, the core scenario was assessed by selecting the no/low-regret investment for each preferred solution, across the demand and technology scenarios, not a combination of benign scenarios only for each driver of uncertainty. The core pathway solutions include allowances for monitoring, investigations and other activities to ensure other options can be efficiently implemented should the need to switch pathways arise in the future

4.52 Table 4-5 shows the overall costs associated with the range of plausible futures, as determined using the approaches described in the previous paragraphs.

Plan component	Total cost (2025-2050) (£bn)		
	Preferred plan pathway	Core pathway	Most adverse pathway
Reducing storm overflow discharges	11.8	11.4	14.8
Protecting properties from sewer flooding	20.2	18.7	21.1
Addressing sewage treatment works compliance risks	1.4	1.1	1.4
All components	**33.3**	**31.2**	**37.3**

Table 4-5 Costs associated with the range of plausible futures for each component of our preferred plan (£bn)

Comparing our preferred plan against the range of plausible futures

4.53 We compared our preferred plan against the range of plausible futures, to inform our selection of alternative pathways.

4.54 Table 4-6 shows the programme of solutions selected within our preferred plan and the overall cost associated with reducing storm overflow discharges and protecting properties from sewer flooding. These are compared against the core pathway and the most adverse pathway.

4.55 Against each of the solution types, we have provided justification as to why they have been included in our preferred plan.

4.56 The table shows that our preferred plan is aligned to a no- and low-regret (core) pathway up to 2040, as the package of investments we have profiled in the near term shows limited variation; the forecasts have a similar impact across the scenarios we tested (except for demand). There are very minor differences between 2030 and 2040 (for example, network improvements (km) are 1.5% less, when comparing the core pathway to the preferred plan). The differences become significant from 2040 onwards across all scenarios, particularly for the most adverse scenario.

4.57 Beyond 2040, we consider our preferred plan pathway to be the best assessment of future uncertainties, based on the information that has driven our current forecasts. Our preferred plan ensures our wastewater services are robust and resilient to future pressures. We have devised alternative pathways to ensure that our ambition can be met across the range of plausible futures, as our planning forecasts may change in the future.

4.58 Table 4-6:

- Paragraph 4.33 details the key observations regarding the differences between common reference scenarios, for each solution type; these are also applicable when considering the core and most adverse pathways
- Surface water management16 network improvements and storage at STWs is required in all/most scenarios. 2025-2030 investments are highlighted as being needed in the short term, across all scenarios
- Sewer lining is required in all scenarios and is also needed to meet short-term needs
- Enhancements to our modelling capabilities will enable us to better understand risks associated with surface water networks, provide better definition of the scale and type of solutions required and facilitating partnership working

[16] Refer to Table 4-3, Note 1 for the reasons for the limited variation in the package of investments across the pathways

Preferred solution type	Unit	Planning horizon	Preferred plan	Needed in all scenarios	Needed in most scenarios	Needed to keep future options open	Needed in the short term	Core pathway	Most adverse pathway
Reducing storm overflow discharges									
Surface Water Management	Hectares managed	2025-2030	80	Yes			Yes	80	80
		2030-2035	20	Yes				20	20
		2035-2040	360	Yes				360	360
		2040-2045	190	Yes				190	190
		2045-2050	470	Yes				470	470
Network Improvements (storage)	000's of m3	2025-2030	5	Yes			Yes	5	5
		2030-2035	1,448		Yes			1,445	1,451
		2035-2040	1,574		Yes			1,545	1,704
		2040-2045	1,391		Yes			1,332	1,578
		2045-2050	311		Yes			222	1,422
Network Improvements (new sewers)	Km	2035-2040	4	Yes				4	4
		2045-2050	10		Yes			7	46
Storage at STWs	000's of m3	2025-2030	22	Yes			Yes	22	22
		2030-2035	289		Yes			289	289
		2035-2040	481		Yes			473	518
		2040-2045	621		Yes			570	779
		2045-2050	15		Yes			11	70
Sewer Lining	Km	All	661	Yes			Yes	661	661
Total cost	**£bn**		**11.8**					**11.4**	**14.8**

Protecting properties from sewer flooding

Surface Water Management	Hectares managed	2025-2030	100	Yes			Yes	100	100
		2030-2035	50		Yes			40	50
		2035-2040	610		Yes			600	610
		2040-2045	2,440		Yes			2,430	2,440
		2045-2050	3,270		Yes			3,230	3,300
Network Improvements (storage)	000's of m3	2025-2030	-					-	-
		2030-2035	13		Yes			5	18
		2035-2040	145		Yes			109	169
		2040-2045	633		Yes			559	680
		2045-2050	1,124		Yes			1,000	1,216
Network Improvements (new sewers)	Km	2025-2030	53	Yes			Yes	53	53
		2030-2035	2		Yes			1	3
		2035-2040	15		Yes			1	27
		2040-2045	229		Yes			188	255
		2045-2050	674		Yes			598	726
Sewer Lining	Km	All	1,190	Yes				1,190	1,190
Total cost	**£bn**		20.2					18.7	21.1

Reducing storm overflow discharges and Protecting properties from sewer flooding

Surface Water Management	Hectares managed	2025-2030	180	Yes			Yes	180	180
		2030-2035	70		Yes			60	70
		2035-2040	970		Yes			960	970
		2040-2045	2,630		Yes			2,620	2,630
		2045-2050	3,740		Yes			3,700	3,770
Network Improvements (storage)	000's of m3	2025-2030	5	Yes			Yes	5	5
		2030-2035	1,461		Yes			1,450	1,469
		2035-2040	1,719		Yes			1,654	1,873

		2040-2045	2,024		Yes			1,891	2,258
		2045-2050	1,435		Yes			1,222	2,638
Network Improvements (new sewers)	Km	2025-2030	53	Yes			Yes	53	53
		2030-2035	2					1	3
		2035-2040	19		Yes			5	31
		2040-2045	229		Yes			188	255
		2045-2050	684		Yes			605	772
Storage at STWs	000's of m3	2025-2030	22	Yes			Yes	22	22
		2030-2035	289		Yes			289	289
		2035-2040	481		Yes			473	518
		2040-2045	621		Yes			570	779
		2045-2050	15		Yes			11	70
Sewer Lining	Km	All	1,851	Yes			Yes	1,851	1,851
Enhancing our modelling capabilities			Yes			Yes		Yes	Yes
Partnership working			Yes			Yes		Yes	Yes
Total cost	£bn		31.9					30.1	35.9

Key

(green)	The scope (and cost) of solutions is the same or more than the preferred plan
(orange)	The scope (and cost) of solutions is less than the preferred plan

Notes

1	Solution type descriptions are as detailed in the key to Table 4-3.
2	The notes for Table 4-3 are also applicable to this table.
3	Paragraph 4.33 details the key observations regarding the differences between common reference scenarios, for each option type; these are also applicable when considering the core and most adverse pathways.

Table 4-6 Comparing our preferred plan to the core and most adverse pathways (reducing storm overflow discharges and protecting properties from sewer flooding)

Preferred solution type	Unit	Planning horizon	Preferred plan	Needed in all scenarios	Needed in most scenarios	Needed to keep future options open	Needed in the short term	Core pathway	Most adverse pathway
Treatment process technologies	£bn	2025-2030	0.33	Yes			Yes	0.33	0.34
		2030-2035	0.61		Yes			0.43	0.63
		2035-2040	0.30		Yes			0.25	0.31
		2040-2045	0.04		Yes			0.05	0.05
		2045-2050	0.07		Yes			0.06	0.07
		ALL	1.35					1.13	1.38
Protecting our sewage treatment works from river flooding (see note)	£bn	All	0.02	Yes				0.02	0.02
Total	£bn	All	1.37					1.14	1.39

Solution type	Description
Treatment process technologies	Implementation of a range of different technologies identified to enhance the performance of the STW, through either retrofitting or new-build options. This will include the use of more intensive wastewater treatment processes which have the capacity to meet future demands.
Protecting our sewage treatment works from river flooding	Implementation of measures such as the construction of bunds to protect our assets from high river levels

Note
For completeness, the costs above include a total of £16m (rounded to £0.02bn in the table, across all scenarios) for a package of investments to protect our sewage treatment works from river flooding. We have not undertaken adaptive planning on this package as the impacts of future scenarios on river flooding requires further work. We will explore this in cycle 2.

Table 4-7 Comparing our preferred plan to the core and most adverse pathways (change in cost: addressing sewage treatment works compliance risks) (£bn)

4.59 Table 4-7 shows there is a significant difference in sewage treatment works investment between the core and other pathways from 2030 onwards. Beyond 2030, we consider our preferred plan pathway to be the best assessment of future uncertainties, based on the data that has informed our current forecasts. We have devised alternative pathways to ensure that our ambition can be met across the range of plausible futures (see section 5).

4.60 From our testing of the preferred plan we have identified the key factors that may drive different pathways as:

- Climate change: this has a significant impact on our programme of investments to reduce storm overflow discharges and protect properties from sewer flooding:

- Our programme of investments to protect properties from sewer flooding has been costed at £20.2bn, using a 15% ('central estimate') forecast for the increase in rainfall intensity in severe storms, due to climate change, by 2050. However, this forecast could range between 8% (representing a low global emissions climate change scenario) and 20% (representing a high global emissions scenario), which could change the cost of the programme (£18.7bn for the low scenario, £21.1bn for the high scenario)
- A high global emissions climate change scenario may require over 25% more investment in the longer-term (up to 2050), to achieve our ambition of reducing storm overflow discharges, compared to our preferred plan (increasing from a preferred plan of £11.8bn to £14.8bn, representing a high global emissions climate change scenario)

- Demand: the uncertainty in future forecasts for population growth has a significant impact on our programme of investments to address sewage treatment works compliance risks. Lower demand forecasts than those used in the development of our preferred plan could lead to a 16% reduction in investment in the longer-term (from £1.37bn to £1.14bn)

4.61 Uncertainty in both climate change and demand can have a significant impact on the long-term cost of the programme and/or pace of investment.

5 Understanding if and when we need to change our plan

Progress

5.1 Having established how different future scenarios may drive different plans, in this section we focus on what might be the triggers to switch from our preferred plan to the different plans, creating an alternative pathway to the one we were previously following (see Figure 4-2). We have devised alternative pathways that meet our ambition over the range of plausible futures, as determined from the scenario testing.

Reducing storm overflow discharges and protecting properties from sewer flooding

5.2 The testing has identified that future uncertainty in the investment requirements for reducing storm overflow discharges and protecting properties from sewer flooding are primarily driven by climate change (see

5.3 Figure 4-5). We have therefore considered these together, when devising alternative pathways.

5.4 Figure 5-1 and Figure 5-2 show that there is little difference between the overall cost to 2040 following any pathway; the departure in investment to address future drivers of uncertainty occurs between 2040 and 2050, principally due to significant divergence in the forecasts for climate change scenarios.

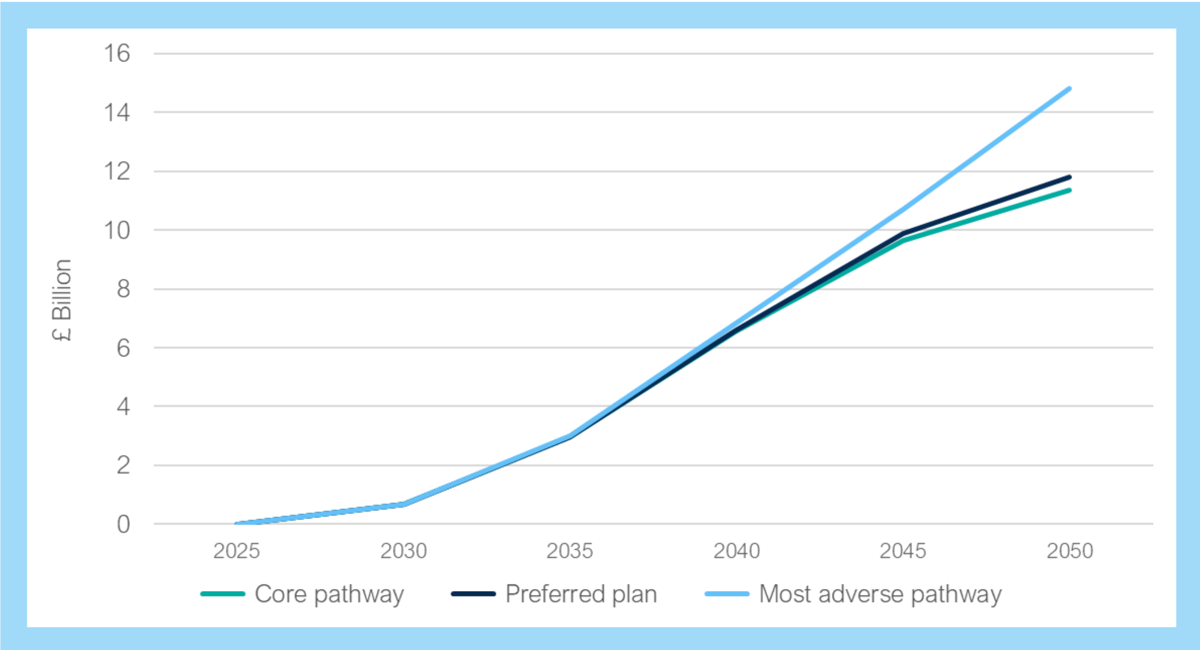


Figure 5-1 Preferred plan cummulative cost compared to the core and most adverse pathways (reducing storm overflow discharges)

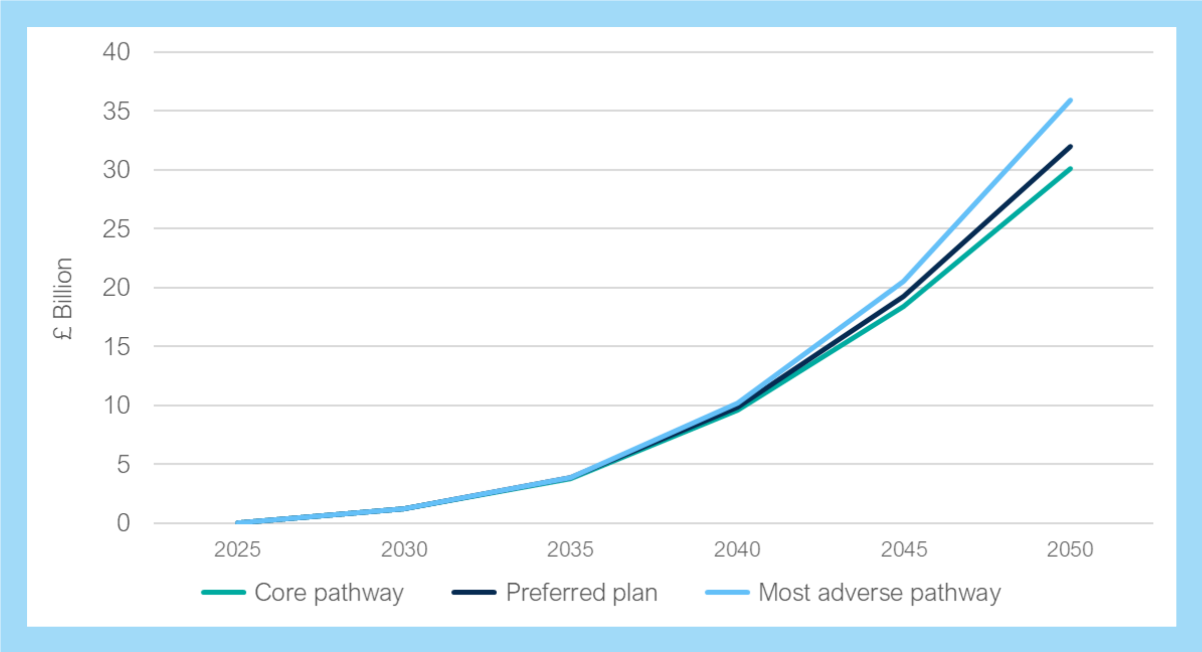


Figure 5-2 Preferred plan cummulative cost compared to the core and most adverse pathways (protecting properties from sewer flooding)

5.5 Therefore, the forecast for climate change might drive a switch to a different pathway. We expect similar forecasts in the near term but in 15 years the forecast might diverge, meaning 2035-2040 is taken as the planning period when we need to decide whether to follow a new pathway (starting at 2040) or remain on the preferred plan pathway.

5.6 Similar decisions will be required during the following planning period (2040-2045), depending on the pathway taken during the previous planning period. The planning forecast at that time will provide the evidence as to whether the best course of action is to:

- Switch to the most adverse pathway
- Remain on the preferred plan pathway
- Switch to the core pathway

5.7 Further pathways between these ranges can be considered, both ahead of and beyond the 2040 ‘trigger point’. These have not been subsequently considered in this document to avoid the complexity of multiple decision points (which will result in many alternative pathways).

5.8 Based on the above we have identified four alternative pathways to the preferred plan:

- Switch from the preferred plan to the most adverse pathway in 2040
- Switch from the preferred plan to the core pathway in 2040
- Switch from the preferred plan to the most adverse pathway in 2045
- Switch from the preferred plan to the core pathway in 2045

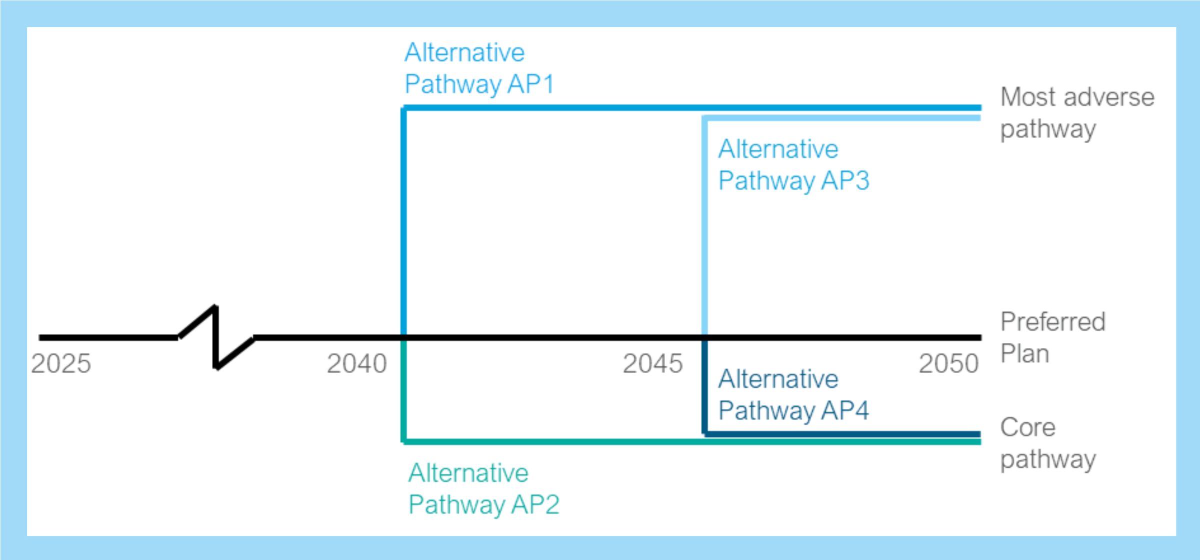


Figure 5-3 Alternative pathways diagram (reducing storm overflow discharges and protecting properties from sewer flooding)

AP	Alternative pathway	Up to end 2030	Up to end 2035	Up to end 2040	Up to end 2045	Up to end 2050
	Preferred plan	1.2	3.8	9.8	19.3	31.9
1	Switch to the most adverse pathway in 2040	1.2	3.8	9.8	20.5	35.9
2	Switch to the core pathway in 2040	1.2	3.8	9.8	18.4	30.1
3	Switch to the most adverse pathway in 2045	1.2	3.8	9.8	19.3	35.9
4	Switch to the core pathway in 2045	1.2	3.8	9.8	19.3	30.1

Note
Costs are presented cumulatively at a 2020/21 price base. The costs reflect those presented in the Ofwat data tables, noting that for the data tables, costs are presented per planning period and are split between reducing storm overflow discharges and protecting properties from sewer flooding.

Table 5-1 Cumulative cost of each alternative pathway (reducing storm overflow discharges and protecting properties from sewer flooding) (£bn)

5.9 We will refine our forecasts during the second cycle of DWMPs, based on the data gathered during the first 5 years of our plan. This will, in turn, enable us to reappraise our alternative pathways.

Addressing sewage treatment works compliance risks

5.10 The testing has identified that future uncertainty in the investment requirements to address sewage treatment works compliance risks are primarily driven by demand (see

5.11 Figure 4-5).

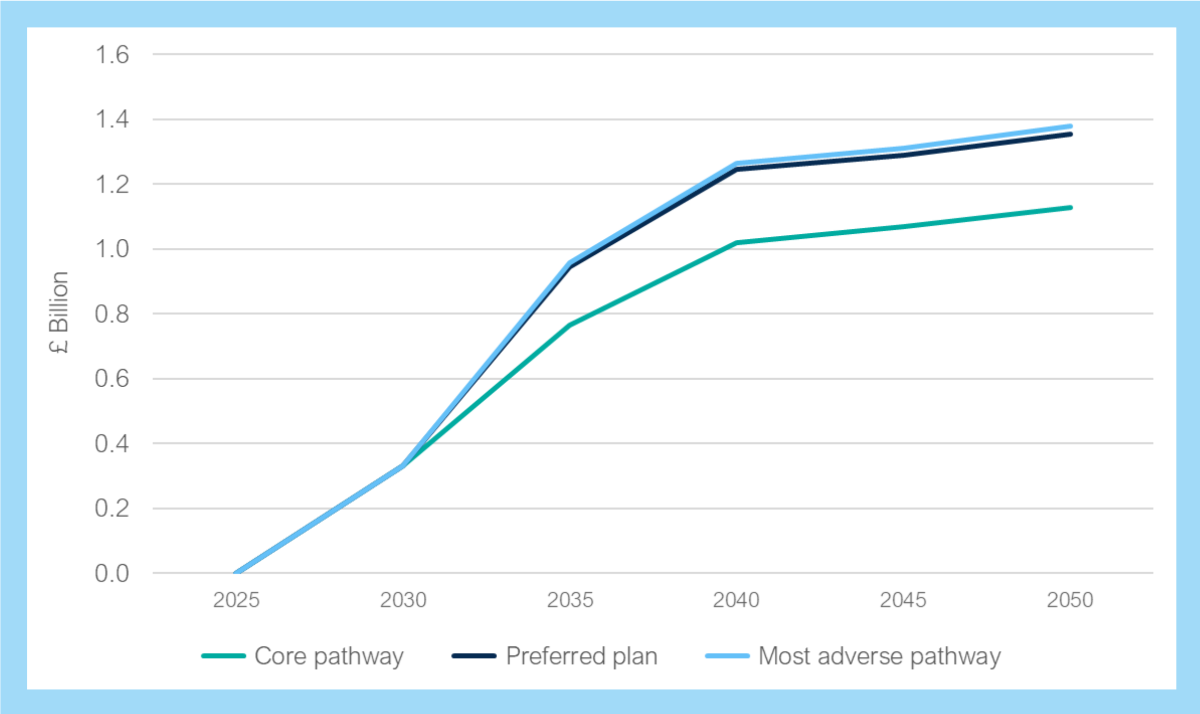


Figure 5-4 Preferred plan cummulative cost compared to the core and most adverse pathways (addressing sewage treatment works compliance risks)

5.12 Figure 5-4 shows that the cost profile of our preferred plan and the most adverse pathway are similar; there is a significant divergence in cost compared to the core pathway from 2030. This is because we predominantly used local plan data (prepared by the Local Planning Authority) when deriving our forecasts, as opposed to, for example, using data prepared by the Office for National Statistics, which is based on extrapolation of historical trends and assumptions of future levels of births, deaths and migrations. The use of local plan data generally results in larger population growth forecasts compared to the use of historical trends.

5.13 We have identified one alternative pathway to the preferred plan to explore those factors likely to have the most significant impact on future investment in treatment, acknowledging that there are likely to be a range of pathways to address site-specific issues and risks. Our alternative pathway represents a switch from the preferred plan to the core pathway in 2030, triggered by a change to demand forecasts.

5.14 While our preferred plan pathway requires a larger package of investments from 2030 onwards compared to the core pathway, we consider our preferred plan pathway to be the best assessment of future uncertainties, based on the information that has driven our current forecasts. We usually use forecasts derived from local plan data when assessing solutions for treatment works compliance risks as they are usually more accurate than relying on historical trends.

5.15 Figure 5-5 shows the alternative pathway for addressing sewage treatment works compliance risks.

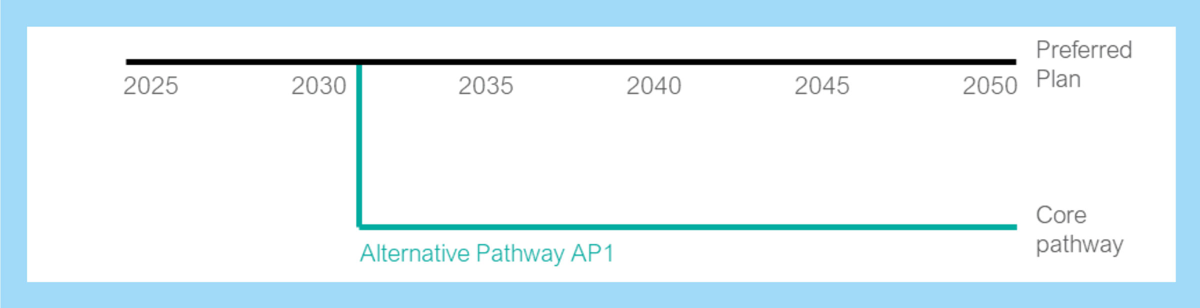


Figure 5-5 Alternative pathway diagram (addressing sewage treatment works compliance risks)

Alternative pathway		Up to end 2030	Up to end 2035	Up to end 2040	Up to end 2045	Up to end 2050
	Preferred plan	0.33	0.95	1.26	1.30	1.37
AP1	Switch to the core pathway in 2030	0.33	0.77	1.03	1.08	1.14

Notes
1. For completeness, the costs above include a total of £16m (across all pathways) for a package of investments to protect our sewage treatment works from river flooding. We have not undertaken adaptive planning on this package as the impacts of future scenarios on river flooding requires further work. We will explore this in cycle 2.
2. Costs are presented cumulatively at a 2020/21 price base. The costs reflect those presented in the Ofwat data tables, noting that for the data tables, costs are presented per planning period and are split between addressing sewage treatment works compliance risks and protecting our sewage treatment works from flooding.

Table 5-2 Cumulative cost of the alternative pathway (addressing sewage treatment works compliance risks) (£bn)

5.16 The alternative pathways for all preferred plan components have been combined and are shown diagrammatically in Figure 5-6.

5.17 Creating a different pathway from the preferred plan, in 2030, for our sewage treatment works compliance component requires a further four alternative pathways for our storm overflows and sewer flooding components (when combining all components). This results in a total of nine alternative pathways:

- One pathway for sewage treatment works compliance (switching from the preferred plan pathway)
- Four pathways as previously described for storm overflows and sewer flooding (switching from the preferred plan pathway)
- A further four pathways for storm overflows and sewer flooding, repeating the above, but switching from a pathway that represents a preferred plan for these components, but a core pathway for the sewage treatment works compliance component

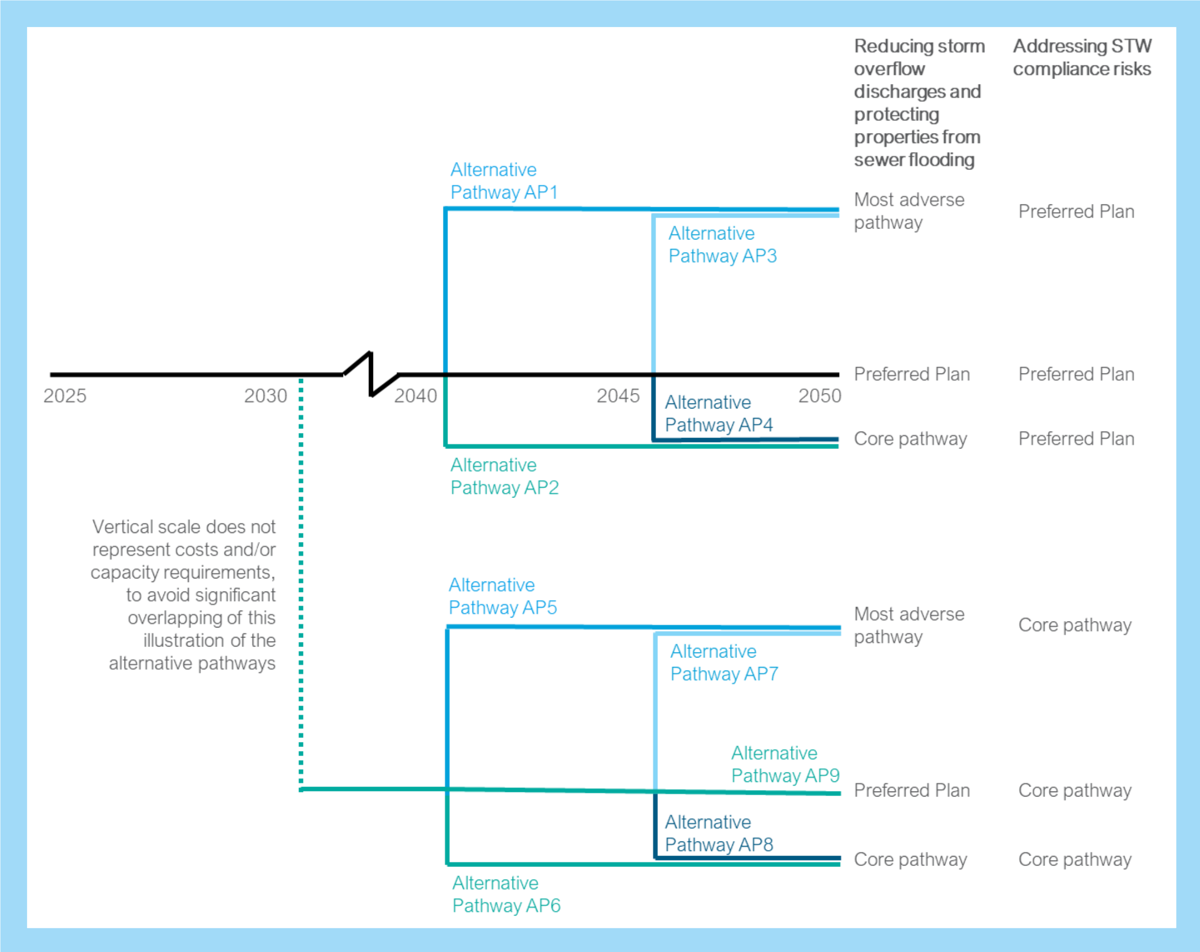


Figure 5-6 Alternative pathways (all preferred plan components)

AP	Reducing storm overflow discharges and protecting properties from sewer flooding	Addressing STW compliance risks	Up to end 2030	Up to end 2035	Up to end 2040	Up to end 2045	Up to end 2050
	Preferred plan	Preferred plan	1.5	4.8	11.1	20.6	33.3
1	Switch to most adverse pathway (2040)		1.5	4.8	11.1	21.8	37.3
2	Switch to core pathway (2040)		1.5	4.8	11.1	19.7	31.5
3	Switch to most adverse pathway (2045)		1.5	4.8	11.1	20.6	37.3
4	Switch to core pathway (2045)		1.5	4.8	11.1	20.6	31.5
5	Switch to most adverse pathway (2040)	Switch to the core pathway in 2030	1.5	4.6	10.9	21.6	37.1
6	Switch to core pathway (2040)		1.5	4.6	10.9	19.4	31.2
7	Switch to most adverse pathway (2045)		1.5	4.6	10.9	20.3	37.1
8	Switch to core pathway (2045)		1.5	4.6	10.9	20.3	31.2
9	Preferred plan		1.5	4.6	10.9	20.3	33.1

Notes
1. Costs are presented cumulatively at a 2020/21 price base. The costs reflect those presented in the Ofwat data tables, noting that for the data tables, costs are presented per planning period.
2. For completeness, the costs above include a total of £16m (across all pathways) for a package of investments to protect our sewage treatment works from river flooding. We have not undertaken adaptive planning on this package as the impacts of future scenarios on river flooding requires further work. We will explore this in cycle 2.

Table 5-3 Cumulative cost of the alternative pathways (all preferred plan components) (£bn)

Understanding the trigger points

5.18 Trigger points for our DWMP can take several forms including:

- Strategic decisions
- Changes in forecasts for drivers of uncertainty
- Technological advances

5.19 Strategic decision points are generally driven by planning requirements that may or may not be directly related to the risks our DWMP addresses. For example, step changes in the amount of surface water ingress that enters our networks may arise as a result of actions by other stakeholders to address commitments within Green Infrastructure Strategies. This would help facilitate collaboration with partners at a catchment level on the roll-out of surface water management schemes, supported by better information from our enhanced monitoring proposals. While potentially benefiting the management of the risks that our DWMP aims to address, these opportunities may arise as a result of the strategies developed by local authorities, rather than as a direct consequence of the DWMP.

5.20 Technology advances, such as innovation in new treatment processes, enable a change to an alternative delivery mechanism. For example, advances in low-footprint treatment technology, or the ability to achieve large scale energy generation from wastewater. We have identified a number of dependencies where emerging or developing technologies may provide more effective and efficient solutions to our wastewater challenges.

5.21 Changes in forecasts for drivers of uncertainty, such as growth and climate change, will also impact compliance and performance. To manage the inherent uncertainty in forecasts we have developed options / delivery mechanisms that can provide flexibility to deal with risks under alternative future scenarios.

5.22 Our analysis has demonstrated that climate change is the key factor that may drive (or 'trigger') different pathways (see paragraph 4.60) for our package of investments to reduce storm overflow discharges and protect properties from sewer flooding.

5.23 While we will review and modify our adaptive plans during subsequent DWMP cycles, based on current forecasts we have previously identified that key decisions need to be made ahead of our trigger points in 2040 and 2045 (see Figure 5-6). These are the points at which an alternative adaptive pathway might need to be followed, as from 2040 the core and adverse pathways begin to show significant divergence from our preferred plan, driven by the forecast for climate change (see Figure 5-1 and Figure 5-2). Our decisions will be informed by the climate change forecasts available at the time.

5.24 When considering our sewage treatment works compliance risks, the key factor 'triggering' a move to an alternative pathway is change in demand forecasts (see paragraph 4.60). Adaptive planning for our sewage treatment works is generally at a more granular level that for our networks. We keep demand forecasts under constant review and plan investments accordingly.

5.25 We have proposed preparatory work early in our next planning cycle, to enable us to make better informed decisions and to improve our forecasts and understanding of risk. Improvements in our understanding and modelling of groundwater infiltration and surface water interconnections will reduce uncertainties in our knowledge and performance of our systems. It will inform the scale and pace of options required to remove unwanted flow from our systems, providing an adaptive response to changes in our understanding of future risks.

5.26 We will work with the water industry and supporting research organisations to ‘fast track’ the updating of our modelling tools in response to the latest climate science (e.g., translating latest UK climate projections into forecasts that can be used when planning at an asset level).[17]

5.27 In the next planning period (2025-2030) we also plan to increase the work we do in partnership with other bodies that have responsibilities for drainage, to co-create and deliver an extensive surface water management programme. Through working with others, we aim to understand how such activities can be scaled-up to achieve the ambitious future extent of investments needed to achieve our overall DWMP ambition.

Having a monitoring programme in place

5.28 By monitoring system performance in the future, and re-evaluating our forecasts for climate change and demand, we can deliver our solutions in an adaptive and phased approach. Alternative pathways can therefore be refined in subsequent cycles of our DWMP.

5.29 Monitoring parameters for our plan components are shown in Table 5-4 and key parameters are described below.

5.30 Our monitoring programme will allow us to review our predictions against actual observations and hence update our projections in future DWMP cycles.

- As described in the previous section, adaptive planning for our package of investments to reduce storm overflow discharges and protect properties from sewer flooding will largely be driven by climate change science. However, at a catchment level, we can make use of technological developments to deliver targeted investments. Our increasing network of intelligent monitoring points will allow us to identify catchment wide trigger points for investment. The trigger points will relate to the reduction of system capacity relative to our performance objective target. For example, when the peak water levels exceed a risk-based threshold then an investment decision will be required
- Similarly, our treatment works are monitored for compliance metrics. Where performance reaches a risk-based threshold (80% of permit for quality, 90% of permit for flow) then an investment decision can be undertaken

[17] Noting that DWMP cycle 2 statutory guidance may dictate our approach.

Component			Parameter/indicator to be monitored	Type of indicator	Application (planning level)
Reducing storm overflow discharges	Protecting properties from sewer flooding	Addressing sewage treatment works compliance risks			
✓✓✓	✓✓✓	✓	Climate change forecasts	Leading	Strategic & catchment/asset
✓✓✓			Storm overflow discharge frequency and volume (forecast from modelled assessments)	Leading	Catchment/asset
✓✓✓			Discharge frequency (from event and duration monitors)	Lagging	Catchment/asset
✓✓✓			River quality monitoring upstream and downstream of storm overflow discharges	Lagging	Catchment/asset
✓✓✓	✓✓✓	✓	Network capacity (from smart monitors)	Lagging	Catchment
✓✓✓	✓✓✓		Recorded rainfall (e.g., from radar observations or rain gauges)	Lagging	Catchment
	✓✓✓		Number of property sewer flooding incidents (forecast from modelled assessments)	Leading	Catchment
	✓✓✓		Number of property sewer flooding incidents (recorded)	Lagging	Catchment
✓✓	✓✓	✓✓✓	Demand forecasts	Leading	Strategic & catchment/asset
			Treatment works compliance forecasts (from modelled assessments)	Leading	Catchment/asset
✓[1]	✓[1]	✓✓✓	Rate of change of household water consumption	Lagging	Catchment/asset
		✓✓✓	Treatment works compliance metrics (recorded)	Lagging	Catchment/asset

Key

Leading indicator
Predicts future conditions/performance
Lagging indicator
Assesses current conditions/performance

Relevance of indicators to each component of the plan:
✓✓✓ High
✓✓ Medium
✓ Low

Note
1. This may have a significant impact at a localised level

Table 5-4 Key monitoring parameters for our plan components

5.31 Our next cycle of DWMPs will also benefit from the further information that will be gathered to enable us to better understand storm overflow discharges and their impact on the environment:

- We will benefit from a longer dataset from event duration monitors, to better understand trends over time and factors that cause variation in performance
- In the next planning period (2025-2030) we will also be installing river quality monitors upstream and downstream of storm overflow discharge locations. This will allow us to refine and prioritise our investment plans, based on a greater understanding of the environmental impact of the discharges

5.32 Monitoring will also help increase confidence in our network models which further reduce uncertainties in our knowledge and performance of our systems.

6 Conclusions

Progress

6.1 We have applied an adaptive planning framework aligned to Ofwat's LTDS guidance. It was applied at an overall plan level and at plan component level:

- Reducing storm overflow discharges
- Protecting properties from sewer flooding
- Addressing sewage treatment works compliance risks

6.2 The main insights for our storm overflow discharge reduction plans are:

- Of the three common reference scenarios tested, climate change is the key factor that may drive different pathways over the longer term of the plan (beyond 2040). It has a significant impact on our programme of investments to reduce storm overflow discharges
- A high global emissions climate change scenario may require over 25% more investment in the longer-term (up to 2050) to achieve our ambition of reducing storm overflow discharges, compared to our preferred plan (increasing from a preferred plan of £11.8bn to £14.8bn)
- However, climate change forecasts do not drive different plans over the medium term as the investment requirements are driven by ambitious environmental targets set out in legislation. Our preferred plan has only minor differences to the core pathway to 2040; the core plan has 1.5% less network improvements (km) compared to the preferred plan).
- Anticipating when we may need to change pace is a key element of adaptive planning. Current UK climate scenarios suggest a trigger point toward the end of AMP10 representing an effect sufficient to require an adjustment in our planning response. Monitoring this trigger point will reflect the publication of new climate scenarios by the Met Office (UK Climate Projections)
- The divergence in climate scenarios beyond 2040 allows us to monitor and accelerate or decelerate the pace of the plan as needs, retaining flexibility. In addition, because our solutions are small, dispersed, or modular, this makes it easier to adjust pace. This also allows us to undertake investigations and monitoring to better prioritise schemes ensuring more efficient and effective investment. Our plan does not have large, single point, long lead time infrastructure solutions which would make this impossible
- We have devised alternative pathways to ensure that our ambition can be met across the range of plausible futures, as our planning forecasts may change in the future. Our ability to switch to alternative pathways reflects the nature of the solutions we have identified and means we avoid the risk of short to medium-term investment decisions that may not materialise in the long-term (maladaptation)
- Beyond 2040, significant climate change uplifts are forecast, and our preferred plan tracks a central position between the core and adverse forecasts
- The next cycle of DWMPs will also benefit from the further information that will be gathered to enable us to better understand the impact of storm overflow discharges on the environment
- Adaptive planning for our package of investments to reduce storm overflow discharges will largely be driven by climate change science. By monitoring system performance in the

future and re-evaluating our forecasts for climate change (and demand), we can deliver our solutions in an adaptive and phased approach. Alternative pathways can therefore be refined in subsequent cycles of our DWMP
- At a catchment level, we can make use of technological developments to deliver targeted investments. Our increasing network of intelligent sewerage network monitoring points will allow us to identify catchment wide trigger points for investment. The trigger points will relate to the reduction of system capacity relative to our performance objective target

6.3 The main insights for sewer flooding are:
- Climate change is also a key driver of alternative pathways for our programme of investments to protect properties from sewer flooding
- Our programme of investments to protect properties from sewer flooding has been costed at £20.2bn, using a 15% ('central estimate') forecast for the increase in rainfall intensity in severe storms, due to climate change, by 2050. However, this forecast could range between 8% (representing a low global emissions climate change scenario) and 20% (representing a high global emissions scenario), which could change the cost of the programme (£18.7bn for the low scenario, £21.1bn for the high scenario)
- Our sewer flooding solutions are multiple, small, modular and dispersed across our region. This makes the plan easier to accelerate or decelerate according to how the climate is changing
- General observations above for storm overflow discharges are also applicable to sewer flooding

6.4 The main insights for sewage treatment works are:
- Of the three common reference scenarios tested, demand is the main driver of alternative pathways impacting on our programme of investment to ensure long term compliance of our sewage treatment works.
- The uncertainty in future forecasts for population growth has a significant impact on our programme of investments to address sewage treatment works compliance risks. Lower demand forecasts than those used in the development of our preferred plan could lead to a 16% reduction in investment in the longer-term (from £1.37bn to £1.14bn)
- Demand scenarios begin to drive alternative pathways beyond 2030. As a result, our overall 25-year plan costs range from £1.14bn to £1.39bn, compared to our preferred plan at £1.37bn
- In the period to 2030 our preferred plan aligns with the core pathway, providing a no- / low-regret pathway in the short-term
- We have identified one alternative pathway to the preferred plan to explore those factors likely to have the most significant impact on future investment in treatment, acknowledging that there are likely to be a range of pathways to address site-specific issues and risks. Our alternative pathway represents a switch from the preferred plan to the core pathway in 2030, triggered by a change to demand forecasts
- Our core pathway is based on ONS long term population projections whereas our preferred plan draws on local development and development planning population data and forecasts. We have observed significant planning and development pressures related to high population growth areas in recent years across our region (for example, current and future proposals for new developments in London's Isle of Dogs). Current forecasts indicate this trend will continue, at least for the short to medium-term, and there is a

significant departure from ONS forecasts. We have relied on this more local data to develop our preferred plan; as a result, our preferred plan represents an adverse future pathway

- While our preferred plan pathway requires a larger package of investments from 2030 onwards compared to the core pathway, we consider our preferred plan pathway to be the best assessment of future uncertainties, based on the information that has driven our current forecasts. Furthermore, as our solutions are modular, we can adjust the pace of delivery to match the demand, maintaining a no / low regret pathway for our plan
- Our adaptive plan for sewage treatment works compliance includes a number of alternative treatment streams and alternative investment decisions. Our preferred plan includes investment in investigations during the first 5 years of our DWMP (2025-2030) to inform the initial selection of pathway
- At a catchment level we have developed long-term adaptive plans up to 2100 for our Beckton and Mogden STW catchments. The adaptive pathway approach identifies core and alternative pathways in response to existing technology and emerging innovation; asset renewal schemes; commercial opportunities in waste recovery; and synergies with our water resource management plan, to reduce the risk of short-term decision making impacting longer-term solutions

6.5 As a result of applying an adaptive planning framework to our plan we consider that the key features that make the overall £33.3bn investment, with £1.5bn between 2025 and 2030, adaptable to different futures are:

- Our preferred plan is based on the most certain growth and climate change forecasts in the near term. In the longer term, we consider our preferred plan pathway to be the best assessment of future uncertainties, based on the information that has driven our current forecasts
- Our preferred plan comprises a range of different types of solutions of different sizes, dispersed across our catchments. This provides the basis for developing an adaptive response to a range of different futures
- Our approach is flexible, comprising network solutions such as multiple small to medium surface water management solutions that can be scaled up or down, or delivered sooner or later, in response to differing growth and climate change patterns. It is also focussed on interventions that allow us to better understand surface water interaction and how we can best manage that. working in collaboration with others to deliver environmental and wellbeing benefits. In the case of treatment solutions, these can be implemented depending on changing futures
- Modular design of sewage treatment works upgrades and the small to medium, dispersed nature of network solutions (with surface water management being considered first) make the plan easy to change tack. There is no reliance on single locality, large infrastructure solutions that risk being assets being oversized/under-utilised if forecast don't materialise
- Regular monitoring using leading (e.g., system capacity) and lagging measures (e.g., system performance) will ensure we can change the plan at the most appropriate point in time

6.6 We recognise that our DWMP adaptive pathway planning will mature over further cycles and our focus going forward will be on:

- Developing a programme of monitoring and modelling of surface water volumes and connections to our systems so that we can focus measures on surface water removal and, where appropriate, refine planned investments in our networks
- Establishing the importance of technology and innovation, such as smart networks, in informing our deliverability and pace of delivery of surface water management solutions. In addition, allowing time to explore technology and innovation improvements to maximise carbon efficiency when implementing our plan
- Continuing to map current and emerging innovation in treatment technologies for STW enhancements to provide resilience to technology change
- Ensuring option flexibility, allowing us to scale interventions up or down as we learn more about the risks and uncertainties in our plan

6.7 By monitoring system performance over the plan period and re-evaluating our forecasts for climate change and growth, we can reappraise our alternative pathways throughout subsequent cycles of our DWMP and deliver our solutions in an adaptive and phased approach.

Glossary

Term	Description
1 in 30-year storm	A storm that has a 1 in 30 chance (3.33% probability) of being equalled or exceeded in any given year. This does not mean that a 30-year flood will happen regularly every 30 years, or only once in 30 years.
1 in 50-year storm	A storm that has a 1 in 50 chance (2% probability) of being equalled or exceeded in any given year. This does not mean that a 50-year flood will happen regularly every 50 years, or only once in 50 years.
Asset Management Plan (AMP)	A five-year planning cycle used by English and Welsh water industry regulators to set allowable price increases for privately owned water companies and for the assessment of performance indicators such as water quality and customer service.
Baseline Risk and Vulnerability Assessment (BRAVA)	Following Risk Based Catchment Screening (RBCS), more detailed risk assessments on those catchments where we believed there was an adverse risk to performance over time. We modelled their performance to 2020 (baseline), 2030, 2035 and 2050.
Business Plan	Business Plans are produced by water companies every 5 years. They set out their investment programme to ensure delivery of water and wastewater services to customers. These plans are drawn up through consultation with the regulators, stakeholders and customers and submitted to Ofwat for detailed scrutiny and review.
Catchment Strategic Plans (CSPs)	Summary reports to promote system thinking across large wastewater catchments. These provide early sight of our final plans enabling co-authoring opportunities for our stakeholders. Each document outlines the challenges that the catchment will face in the future and the long-term plans to address these issues.
Combined sewer	A sewer designed to receive both wastewater and surface water from domestic and industrial sources to a treatment works in a single pipe.
Customer Challenge Group (CCG)	An independent body that challenges both our current performance and our engagement with customers on building our future plans.
Cycle 1 and Cycle 2 DWMP	Our current DWMP is referred to as Cycle 1, it covers a planning period of 2025-2050. Our next plan will be published in five years' time and is referred to as our Cycle 2 DWMP, it will cover a planning period of 2030-2055.
Department for Environment, Food and Rural Affairs (Defra)	UK government department responsible for safeguarding the natural environment, food and farming industry, and the rural economy.
Drainage and Wastewater Management Plan (DWMP)	A Drainage and Wastewater Management Plan (DWMP) is '*a long-term strategic plan that sets out how wastewater systems, and the drainage networks that impact them, are to be extended, improved and maintained to ensure they are robust and resilient to future pressures*'. The planning period is 25 years, from 2025 to 2050. DWMP is iterated every five years; the first known as 'Cycle 1', published as a final plan in May 2023.
dDWMP	The draft version of the Drainage and Wastewater Management Plan, published in June 2022.
fDWMP	The final version of the Drainage and Wastewater Management Plan, to be published in May 2023.
Dry Weather Flow (DWF)	Dry Weather Flow is the average daily flow to a Sewage Treatment Works (STW) during a period without rain.

Environment Agency (EA)	UK government agency whose principal aim is to protect and enhance the environment in England and Wales.
EA Pollution Categories 1 to 3	Category 1 incidents have a serious, extensive or persistent impact on the environment, people or property. Category 2 incidents have a lesser, yet significant, impact. Category 3 incidents have a minor or minimal impact on the environment, people or property with only a limited or localised effect on water quality. Further Ofwat guidance available here: WatCoPerfEPAmethodology_v3-Nov-2017-Final.pdf (ofwat.gov.uk)
Event Duration Monitoring (EDM)	Event duration monitoring (EDM) measures the frequency and duration of storm discharges to the environment from storm overflows.
External hydraulic sewer flooding	External flooding occurs within the curtilage of a property due to hydraulic sewer overload. Further Ofwat guidance available here: Reporting-guidance-sewer-flooding.pdf (ofwat.gov.uk)
Foul sewer	A foul sewer is designed to carry domestic or commercial wastewater to a sewage works for treatment. Typically, it takes wastewater from sources including toilets, baths, showers, kitchen sinks, washing machines and dishwashers from residential and commercial premises.
Grey infrastructure	New sewers, sewer upsizing and attenuation storage to provide additional capacity in the wastewater networks. Also covers new pumping stations, rising mains and/or civil structures at STWs.
Green infrastructure	Sustainable surface water management solutions, including sustainable drainage systems (SuDS), that are designed to mimic naturally draining surfaces. Typically applied to surface water or combined sewerage systems, but can also be applied to land, highway or other forms of surface drainage.
Historic England (HE)	A non-departmental public body of the government whose aim is to protect the historical environment of England by preserving and listing historic buildings, ancient monuments.
Hydraulic overload	Hydraulic overload occurs when a sewer or sewerage system is unable to cope with the receiving flow.
Internal hydraulic sewer flooding	Flooding which enters a building or passes below a suspended floor caused by flow from a sewer. Further Ofwat guidance available here: Reporting-guidance-sewer-flooding.pdf (ofwat.gov.uk)
L2 Area (Strategic Planning Area)	An aggregation of level 3 catchments (tactical planning units) into larger level 2 strategic planning areas. The level 2 strategic planning areas allow us to describe strategic drivers for change (relevant at the level 2 strategic planning area scale) as well as facilitating a more strategic level of planning above the detailed catchment assessments.
L3 Catchment (Tactical Planning Unit)	Geographical area in which a wastewater network drains to a single STW. Stakeholders may be specifically associated with this area. Includes for surface water sewerage that may exist which serves the wastewater geographical area but drains to a water course.
Lead Local Flood Authorities (LLFAs)	LLFAs are Risk Management Authorities as defined by the Flood and Water Management Act 2010. They have statutory duties with respect to flood risk management, investigating flooding and the compilation of surface water management plans.

Long-Term Delivery Strategy (LTDS)	A requirement by Ofwat on water companies, to ensure that short term expenditure meets long term objectives for customers, communities, and the environment. These will be submitted as part of the Price Review.
Misconnections	Misconnections are where either surface water drainage or foul water is connected to the wrong system e.g., surface water to foul only or foul to surface water systems.
Natural capital accounting	The process of calculating the total stocks and flows of natural resources in a given system, either in terms of monetary value or in physical terms.
Natural England (NE)	A non-departmental public body sponsored by the Department for Environment, Food and Rural Affairs to protect the natural environment in England, helping to protect England's nature and landscapes.
Non-governmental organisation (NGO)	An organisation that operates independently of any government, typically one whose purpose is to address a social or political issue.
Options Development and Appraisal (ODA)	A method to focus the level of planning effort, i.e., proportionate to the risks identified, with a view to providing a measure of consistency across the industry.
Ofwat	The regulatory body responsible for economic regulation of the privatised water and wastewater industry in England and Wales.
PR24	Every five years, water companies set out their plans for what they'll deliver and how much they'll charge customers[18]. Their plans over the next five years should include how they will: • Provide a safe and clean water supply • Provide efficient sewerage pumping and treatment services • Control leaks • Install meters • Maintain pipes and sewers • Maintain and improve environmental standards This process is known as the price review, and the next one will be in 2024, when Ofwat will make its final decisions. We call this PR24.
Risk-Based Catchments Screening (RBCS)	A first-pass screening exercise of catchment vulnerability against 17 different risk indicators. To understand which catchments are low risk catchments and those that are likely to be at risk in the future if not supported by our long-term plan.
Risk Management Authorities (RMAs)	Authorities responsible for Flood Risk as defined in the Flood and Water Management At 2010. These include, Lead Local Flood Authorities, Highway Authorities, Local Planning Authorities, Natural England and the Environment Agency.
Sewage Treatment Works (STW)	A sewage treatment works receives and treats wastewater to a standard legally agreed with the Environment Agency, before it is released back into the environment.
Specific, Measurable, Achievable, Relevant, and Time-Bound (SMART)	A framework for setting effective targets.
Storm overflow discharges	Storm overflows are used to manage excess flows, which typically occur as a result of heavy rainfall. Excess flow that may otherwise have caused flooding is released through a designated outfall to a water course, land area or alternative drainage system.

[18] https://www.ccwater.org.uk/priorities/price-review/

Strategic Environmental Assessment (SEA)	A systematic decision support process to ensure that environmental and other sustainability aspects are considered effectively in policy, plan and programme making.
Surface water sewer	A surface water sewer collects rainwater from domestic and commercial roofs, driveways, patios etc to a local watercourse or suitable surface water drainage system.
Sustainable Drainage systems (SuDS)	Drainage solutions that provide an alternative to the direct channelling of surface water through networks of pipes and sewers to nearby watercourses. SuDS aim to reduce surface water flooding, improve water quality, and enhance the amenity and biodiversity value of the environment. SuDS achieve this by lowering flow rates, increasing water storage capacity and reducing the transport of pollution to the water environment.
Thames Regional Flood and Coastal Committee (TRFCC) area	The TRFCC area was established by the Environment Agency under the Flood and Water Management Act 2010 that brings together members representing the Constituent Authority. Featured TRFCCs are listed here on our DWMP portal: Drainage and Wastewater Management Plan (arcgis.com)
Water Industry National Environmental Programme (WINEP)	The framework under which Defra and the EA require environmental improvements to be delivered by water companies. Guidance is released by regulators, which water companies interpret for their geographical area, and resubmit the outputs back to regulators for endorsement.

Appendix A - Example adaptive pathways for our major sewage treatment works in London

Application of adaptive pathways to London sewage treatment works

A.1 The sewage treatment works (STWs) that serve London are among the biggest and most complex in the UK. Ensuring that the works are resilient to future changes is essential to maintaining levels of service to both customers and the environment and ensuring that capacity does not become a constraint to growth.

A.2 We have identified significant uncertainty associated with the future needs at some of our largest treatment works where an adaptive plan would be beneficial, identifying adaptive pathways in response to uncertainties in growth, asset health, developments in innovation and in relation to schemes identified within our WRMP.

Core and alternative pathway technologies

A.3 Our core and alternative pathways utilise new and emerging innovative technologies compared to traditional treatment processes - namely Integrated Fixed Film Activated Sludge (IFAS), Nereda® and Dissolved Air Flotation (DAF). These are explained below to provide context for the adaptive pathways discussed.

A.4 Alternative adaptive pathways are predominantly driven by potential changes in the forecast of growth patterns (resident and transient/working population including post-pandemic population redistribution associated with hybrid working) and other strategy/commercial decisions (for example the promotion of indirect potable re-use, and ammonia recovery). Climate change is less of a direct driver for treatment works as it does not directly impact on the performance measures related to flow and quality. However, more widely, climate change can potentially impact on:

- The ability of STWs to discharge in tidal zones where sea level rise could cause the blocking of outfalls. This issue is currently being considered at Beckton STW and will be monitored at other sites
- Discharge permit conditions - changes in river flows may drive tighter or modified permit conditions, for example a potential move from an ammonia permit to a total nitrogen permit (noting that this change could come about from other sources and not just from a climate change driver). Addressing tighter or modified conditions may require changes in treatment technologies, which would require a pathway change. There are significant uncertainties in the probability and/or nature of such changes. However, the technology considerations, particularly for Beckton STW, do provide a pathway for enabling a measure of resilience against such changes

Integrated Fixed Film Activated Sludge (IFAS)

A.5 Integrated Fixed Film Activated Sludge (IFAS) processes involve adding a carrier material to support attached biomass growth, in addition to the suspended biomass growth, in an Activated Sludge Plant (ASP).

A.6 Activated sludge is a proven secondary biological treatment technology that is used for ammonia and Biochemical Oxygen Demand (BOD) removal. IFAS media allows slower growing (nitrifying) media to attach and grow.

A.7 Use of IFAS as a retrofit into existing ASPs presents the following advantages:

- Fixed film processes are inherently stable and resistant to organic and hydraulic shock loadings
- It increases treatment capacity (which is easy to phase) without the need for extra aeration tanks or larger Final Settlement Tanks (FSTs)
- No increase in solids loading on the FSTs

A.8 IFAS is a relatively new, but proven, technology which is gaining support in the UK as a cost-effective means of increasing a treatment works' capacity, without the need for significant investment in new concrete structures (for example new ASP lanes).

Nereda®

A.9 Nereda® is an advanced biological wastewater treatment technology which utilises ''aerobic granular biomass'' to achieve the required effluent quality.

A.10 Whilst still a relatively new technology, we have experience with the process through the installation of the UK's first fully operational plant at Highworth STW in 2017 (this STW serves a catchment of 9,100 population equivalent).

A.11 More recently in 2021, Nereda® has been fully operational at United Utilities' Blackburn STW, which is the largest Nereda® installation in Europe to date, serving a catchment of 321,500 population equivalent. This helps treat effluent to an extremely high quality, protecting the bathing and shellfish waters downstream of the effluent discharge location.

A.12 The advantages of using Nereda® as an alternative biological treatment step on site include:

- No requirement for Primary Settlement Tanks (PSTs) as a prior treatment step, as the technology utilises crude sewage
- No requirement for external Final Settlement Tanks (FSTs), since the bacteria naturally concentrate in the compact granules, providing good solids settlement within the process
- Nereda® produces a by-product (biopolymer produced by the bacteria in the system) which has commercial potential, or alternatively can be used on-site as a replacement for sludge thickening polymers
- The process offers both biological phosphorous and total nitrogen reduction. In respect of the former, this can reduce the need for chemical precipitation to meet phosphorus permits. In respect of the latter, the process offers benefit where new or tighter total nitrogen permits may be required

Dissolved Air Flotation (DAF)

A.13 Dissolved Air Flotation (DAF) is a proven technology which is typically used for solids removal in potable water treatment. In action, micro air bubbles are used to attach to and float solids for subsequent removal, rather than reliance on particulate settlement. A key benefit is reduced process footprint when comparing flotation and settlement assets.

A.14 When used as an advanced primary settlement treatment stage, DAF provides enhanced BOD and Suspended Solids (SS) removal. It also enhances the biological process which in turn increases ammonia removal.

Beckton STW

Introduction

A.15 Beckton STW is the largest sewage treatment works in the UK and the largest by flow in Europe, serving a population of 4.2 million in North and East London. London's population is forecasted to grow rapidly over the next 30 years, and we are currently seeing changes in catchment use due to Covid-19.

A.16 As with all central London catchments, space for expansion of the works to accommodate for catchment growth and increased flow and loads to the works, is restricted. The major Tideway Tunnel interface with Beckton via the Lee Tunnel is under construction, and therefore the site will receive additional flows through the Beckton STW expansion scheme.

A.17 Our adaptive pathways for Beckton have explored various treatment options that can be implemented to provide a robust and adaptive approach to the increasing demands of this rapidly changing catchment, given the tight land constraints.

Process description

A.18 The existing treatment process comprises of the following steps:

- Inlet works with coarse screening, grit removal channels and fine screens to remove large solids, to protect downstream processes from blockage
- All flow goes to 16 PSTs where solids are settled out and removed from the bottom of the tanks via a primary sludge stream
- Flow from the PSTs are split and fed to three separate ASPs, each with a different flow split. These flow splits can be varied depending on operational requirements
- Flows exit the ASPs and are sent to final settlement tanks (FSTs); individual banks of FSTs serve each ASP - a total number of 88 FSTs are currently installed at Beckton STW
- All flows from the FSTs are sent to the final effluent (FE) outfall which discharges into the River Thames at Barking Creek

Current capacity

A.19 Beckton STW is currently receiving an upgrade to its treatment capacity through an AMP7 (2020-2025) improvement scheme providing the following:

- Upgrade and extension of the inlet works
- Extension to ASP4 including:
  - Two additional aeration lanes
  - Four final settlement tanks
- A new blower house to provide for the increased air requirements in ASP4
- Provision of a minimum of eight primary sludge screens. Surplus activated sludge (SAS) improvements include an additional holding tank and two (with space for two more) gravity belt thickeners housed within a new SAS building

A.20 Beckton's discharge permit governs both the quality of the effluent and flow limits:

- Biochemical Oxygen Demand (BOD) – 18mg/l as a 95-percentile value
- Suspended Solids (SS) – 45mg/l as a 95-percentile value
- Ammonia (AmmN) – range of 2.5mg/l to 5mg/l as a 95-percentile dependent on temperature

- Dry Weather Flow (DWF) – 1,344,000m3/day
- Flow to Full Treatment (FFT) – 27,036l/s

A.21 The STW is considered compliant if the effluent discharge is at or below these values; in assessing compliance risk, the BRAVA identifies that for the quality parameters values at or below 80% of the permit are not considered a risk. Deterioration to above 80% constitutes a risk as 'headroom' has been eroded. On this basis consideration needs to be given to what options there may be to address the eroded 'headroom' and forecast when, in the absence of a solution, non-compliance might be anticipated. For DWF the risk is considered when recorded/forecast flows exceed 90% of permit value.

A.22 In general, new quality solutions will be designed such that they are at 80% of permit at the end of the planning horizon for a specific scheme. The adaptive pathway for Beckton has assumed that the basis of design for the AMP7 work will provide treatment capacity such that the works will achieve 80% of water quality permit values in the final effluent for Suspended Solids (SS), Biochemical Oxygen Demand (BOD) and Ammonia (AmmN) to 2030.

A.23 This is confirmed by the baseline BRAVA assessment (Figure A-1) which indicates that both BOD and SS (note that these have been combined within an assessment termed MCAP which refers to Modelled Capacity (Process)) and AmmN become at risk of exceeding permit in the period before 2050.

	MCAP (SS & BOD)						
	2020	2025	2030	2035	2040	2045	2050
Original BRAVA	94%	101%	104%	107%	109%	112%	114%
Post AMP7 BRAVA	72%	77%	80%	93%	94%	97%	99%

	AmmN						
	2020	2025	2030	2035	2040	2045	2050
Original BRAVA	87%	101%	104%	107%	109%	112%	114%
Post AMP7 BRAVA	72%	77%	80%	93%	94%	97%	99%

Figure A-1 Baseline Beckton STW BRAVA assessment post-AMP7

Strategy

A.24 Ammonia removal presents the most complex challenge and, as such, has been the focus of the adaptive approach. Issues associated with BOD and SS are predominantly managed in the primary treatment and final settlement stages and are more straightforward to deal with (through the provision of additional 'standard' treatment capacity) and are therefore not considered as being primary drivers for a change in pathway.

A.25 In developing our plan, we have considered compliance to 2100 to ensure that the options identified to meet compliance to 2050 are robust and support the treatment strategy to 2100, accepting there is significant uncertainty in forecasting out to this design horizon.

Pathway element	Description	Progressed / discounted	Reasoning
Ammonia recovery on sludge return stream	Ammonia recovery plant on the return stream post-THP / digester dewatering	Discounted	Discounted as a primary option on the grounds that liquor returns (current and future post THP upgrades) are only c3-5% of ammonia load to the works. Recovery of c90% of ammonia from liquor returns may provide a commercial opportunity through reuse pathways but would not provide significant capacity benefit.
Keep ASP2	Keeping ASP2 in place with proactive maintenance to maintain integrity	Progressed	ASP2 is currently functioning, and proactive maintenance is a viable option to extend functional life of the asset.
Decommission and replace ASP2	Decommissioning ASP2 and replacing it with a new system.	Progressed	Presents one of the most robust options and involves replacing ASP2 (which is nearing the end of its structural life) with either: a.) Nereda® plant contained within the footprint of the existing ASP. This option would also include some DAF/IFAS process enhancements impacting PSTs and ASP3 respectively. b.) New bespoke ASP plant with IFAS provision included as a process enhancement, along with DAFs.
Double Stacking	Double stacking of ASP lanes	Discounted	While technically feasible, there is significant uncertainty in deliverability given the potential risks of subsidence on a low-lying site. It would increase biological capacity but there are better alternatives (IFAS/DAF) which would have significantly less delivery risk. Operational costs would also be increased due to the need to pump flows.
'Cloth pile' Primary Filters	Using 'cloth pile' filters in the primary settlement stage (typically used for tertiary treatment).	Discounted	'Cloth pile' filters are widely used as a final effluent treatment post FSTs. However, their use to treat crude wastewater is a new application. Given there is very limited track record, the option is not being recommended for this cycle. It will, however, be reconsidered as part of the wider options appraisal in the next cycle of the DWMP.
Lamella Separators	Lamella separators as a retrofit for final settlement tanks	Discounted	Extensive maintenance (cleaning) is required. Based on our experience at Reading STW this solution has been technically discounted for Beckton STW.
Converting FSTs from circular to rectangular	Shape changes of Final Settlement Tanks from Circular to Rectangular	Discounted	There are significant delivery risks related to the removal of existing tanks and the potential constraints from existing infrastructure. It is recommended that this is considered in more detail in the next cycle of the DWMP, based on better knowledge of site constraints and performance of horizontal FSTs.

Table A-1 Beckton STW – treatment options

Considered options

A.26 Table A-1 summarises the options considered to increase treatment capacity to meet future performance requirements and whether they were progressed to the ODA stage. Technical reasoning for progressing an option to the ODA stage or discounting an option at BRAVA triage stage is provided.

Options developed for adaptive pathway planning

A.27 Table A-1 highlights a key trigger in the form of a strategic decision that is required, and which is fundamental in informing the adaptive delivery approach adopted. The strategic decision is whether ASP2 should be kept in its current form or replaced. The options identified are:

- Keep ASP2 in service as it is, with proactive maintenance to prolong asset life. While feasible, this option carries with it significant risk: asset deterioration, irrespective of maintenance, leads to constraints on treatment capacity and capability – given forecast growth this could put additional strain on other parts of the works and increase compliance risk; costs to maintain capacity and manage asset deterioration continue to rise; and reduced operational flexibility e.g.,, as per current state, structural integrity concerns do not enable IFAS retrofit. In pursuing this route, long-term performance outcomes for the works would require additional process enhancements including DAF and IFAS on primary and other ASP streams respectively

- Decommissioning ASP2 and replacing it (within the same footprint) with either Nereda®, or a bespoke new ASP/IFAS plant. As above, achieving performance outcomes in the longer-term will require additional process enhancements including DAF and IFAS on primary and other ASP streams respectively

A.28 In developing an adaptive delivery plan, irrespective of the strategic decision on ASP2, we have focused on the performance of alternative technology options to potential changes in incoming flow and load growth (with associated load and flow impacts).

A.29 The pathways arising from the initial strategic decision-making point have been mapped onto a line diagram (Figure A-2) and described in Table A 2.

A.30 A strategic start date of 2030 has been selected for options involving the decommissioning of ASP2. This is to allow for current works on site to finish. It should be noted that delaying the decision to decommission will lead to higher costs to provide headroom given growth in the intervening period (flows/loads), which would put more stress on ASP3, ASP4 and the PSTs and FSTs. This would ultimately lead to a greater risk of compliance failure.

Treatment option performance

A.31 The utilisation of chemical dosing, also known as chemically aided precipitation (CAP), to provide capacity headroom in selected pathways where ASP2 is decommissioned, has been discounted on the grounds that, while likely effective, chemical dosing would require significant quantities of bulk chemical (c45,000 tonnes per annum based on an assumed, representative, average dose). This carries with it a significant on-going operational cost, requirement for significant storage capacity, and a significant security of supply risk. Any supply interruption of the required chemicals could lead to major failure at the works with little option to mitigate. On this basis, options TO2 and TO5 have been excluded from decision making process.

A.32 It should be noted that for those pathways where ASP2 is retained, it is considered that even with proactive maintenance, there are structural integrity concerns that would preclude the use of IFAS on ASP2. In addition, flow constraints mean that IFAS would not be appropriate for ASP4. As such, IFAS retrofitting has only been considered for ASP3.

Option number	Option description
Treatment Option 1 (TO1)	Keep ASP2: Option involves retrofit of IFAS to ASP3 (the percentage lane and fill volume having a phased increase over the planning horizon). DAF on primary treatment would be a requirement to be phased in at the end of the planning horizon. The trigger to move to a DAF route will be based on actual works performance and updated impact assessments of forecast growth.
Treatment Option 2 (TO2)	Replace ASP2: 2025 - Investigate feasibility of Nereda® at the scale we would require for Beckton STW. Consideration will be given to establishing a pilot/demonstration plant to allow for confirmation of process benefits (see note). 2030 - Decommission ASP2 and start building replacement Nereda® system, retrofit ASP3 with IFAS and use chemical dosing to provide headroom required from ASP2 being out of service. Bring Nereda® online by 2040. The triggers to move to an enhanced DAF/IFAS combined route post 2045 will be based on actual works performance and updated impact assessments of forecast growth.
Treatment Option 3 (TO3)	Replace ASP2: 2025 - Investigate feasibility of Nereda®. Consideration will be given to establishing a pilot/demonstration plant to allow for confirmation of process benefits (see note). 2030 - Decommission ASP2 and start building replacement Nereda® system, retrofit ASP3 with IFAS and use DAF as a PST replacement to provide headroom required from ASP2 being out of service. Bring Nereda® online by 2040. The triggers to move to an enhanced DAF/IFAS combined route post 2045 will be based on actual works performance and updated impact assessments of forecast growth.
Treatment Option 4 (TO4)	Replace ASP2: 2030 - Decommission ASP2 and start building replacement bespoke ASP/IFAS plant, retrofit ASP3 with IFAS and use DAF as a PST replacement to provide headroom required from ASP2 being out of service. Bring new bespoke ASP online by 2040. The triggers to move to an enhanced DAF/IFAS combined route post 2045 will be based on actual works performance and updated impact assessments of forecast growth.
Treatment Option 5 (TO5)	Replace ASP2: 2030 - Decommission ASP2 and start building replacement bespoke ASP/IFAS plant, retrofit ASP3 with IFAS and use chemical dosing to provide headroom required from ASP2 being out of service. Bring new bespoke ASP online by 2040. The triggers to move to an enhanced DAF/IFAS combined route post 2045 will be based on actual works performance and updated impact assessments of forecast growth.

Note

While there are operational Nereda® plants in the UK, it is still considered a novel technology and, as such, there is risk in pursuing such an approach on such a critical asset as Beckton STW without demonstrating its effectiveness. Establishing a demonstration Nereda® plant to confirm efficacy is considered a pragmatic route. Additionally, should such a demonstration plant be sized such that it could provide equivalent capacity to an existing single PST, this would provide an additional benefit to primary treatment headroom, allowing for more effective management of the primary treatment system e.g., enabling outage for maintenance or, potentially, PST removal and DAF replacement.

Table 3 2 Treatment option pathways for Beckton STW

A.33 Where IFAS is described below in relation to a potential treatment option, two figures are presented. The first gives the percentage of the ASP lane volume that is given over to IFAS, the second gives the percentage media fill in the IFAS zone. As an example, IFAS 30/40 would indicate that 30% of the ASP lane volume is converted to IFAS with a media fill of 40% in the IFAS zone.

A.34 The anticipated performance of each option has been assessed using our existing Beckton STW process model, adjusted to reflect the performance of alternative technology inputs. The outputs are presented in subsequent sections for selected pathways (noting the exclusions of TO2 and TO5 in paragraph A.31).

Treatment Option 1 (T01)

A.35 This pathway keeps ASP2 in place with proactive maintenance planned to maintain asset integrity and increase asset life.

A.36 IFAS is proposed for retrofitting in ASP3 with a phased increase over the planning horizon (2050).

A.37 Table A-3 below shows that compliance can be achieved with an IFAS retrofit to ASP3 of 10% volume replacement with IFAS zone, with media fill of 20% required during 2025-2030. A further increase in volume from 10% to 30% will be required in 2035, with a media fill of 20%. DAF as replacement for 25% of existing PST capacity would be required and phased in at the end of the planning horizon.

Pathway description	Percentage of ammonia permit				
	2025	2030	2035	2040	2050
YEAR 2025 - IFAS (ASP3) 10/20 YEAR 2035 - IFAS (ASP3) 30/20 YEAR 2050 - DAF 25% & IFAS (ASP3) 30/20	66%	80%	54%	59%	50%

Table A-3 Treatment Option 1 (T01) IFAS retrofit to ASP3

Treatment Option 3 (T03)

A.38 This pathway is based on the decommissioning of ASP2 and replacement with Nereda®. Note that the Nereda® design in this scenario (undertaken by Royal Haskoning) is based on a maximum capacity that could be provided if Nereda® was to occupy the existing ASP2 footprint. Given the ASP4 flow constraints (meaning that IFAS would not be appropriate), ASP3 would need to flex to take on board any additional flow/load over the planning horizon.

A.39 Table A-4 shows that compliance can be achieved with an IFAS retrofit to ASP3 of 30% volume replacement with IFAS zone, with media fill of 40% required during 2025-2030. In combination with a 10% replacement of PST flows through DAF, this will allow for the decommissioning and replacement of ASP2 during 2030-2040.

A.40 Installation of DAF to accommodate a further 15% of PST flows by 2040, coupled with Nereda® being brought online in 2040, would provide significant ammonia permit headroom at the end of the DWMP planning horizon (2050) and capacity to meet additional flows/loads in the longer-term (beyond 2050).

A.41 Note that within the performance modelling, it has been assumed that the FSTs currently on the ASP2 stream can be retained and the capacity be made available for use by ASP3 (further work is required to confirm that this would be the case).

Pathway description	Percentage of ammonia permit				
	2025	2030	2035	2040	2050
YEAR 2025 - IFAS (ASP3) 30/40 YEAR 2030 - DAF 10% & IFAS (ASP3) 30/40 & DECOMMISSIONING OF ASP2 YEAR 2035 - DAF 20% & IFAS (ASP3) 30/40 YEAR 2040 - DAF 25% & IFAS (ASP3) 30/40 & Nereda®	64%	70%	65%	79%	28%

Table A-4 Treatment Option 3 (T03) Nereda® retrofit to ASP2

Treatment Option 4 (T04)

A.42 This pathway is based on the decommissioning of ASP2 and replacement with a bespoke ASP/IFAS stream.

A.43 Table A-5 below shows that compliance can be achieved with an IFAS retrofit to ASP3 of 30% volume replacement with IFAS zone, with media fill of 40% required during 2025-2030. In combination with a 10% replacement of PST flows through DAF, this will allow for the decommissioning and replacement of ASP2 during 2030-2040.

A.44 Installation of DAF to accommodate a further 15% of PST flows by 2040, coupled with the new ASP/IFAS stream being brought online in 2040, would provide significant ammonia permit headroom at the end of the DWMP planning horizon (2050) and capacity to meet additional flows / loads in the longer-term (beyond 2050).

Pathway description	Percentage of ammonia permit				
	2025	2030	2035	2040	2050
YEAR 2025 - IFAS (ASP3) 30/40 YEAR 2030 - DAF 10% & IFAS (ASP3) 30/40& DECOMMISSIONING OF ASP2 YEAR 2035 - DAF 20% & IFAS (ASP3) 30/40 YEAR 2040 - DAF 25% & IFAS (ASP3) 30/40 YEAR 2050 - DAF 25% & IFAS (ASP2) 10/20 IFAS (ASP3) 30/40	64%	70%	65%	57%	32%

Table A-5 Treatment Option 4 (T04) ASP/IFAS retrofit to ASP2

Our core and alternative pathways for Beckton STW

A.45 The primary driver for Beckton into the future will be growth in the catchment. While there is significant uncertainty in growth figures (particularly given the pandemic and its potential to modify future behaviours), a single overarching pathway to manage growth through expansion of treatment capacity on-site has been selected as the preferred approach (no feasible options for managing growth elsewhere in the catchment were identified). The potential mechanism for delivering this additional on-site capacity forms the adaptive element of this overarching pathway.

A.46 We will need to take a strategic decision in AMP8 as to whether we keep ASP2 in place; this will involve developing an in-depth understanding of the condition of the ASP2 assets, expected asset life extension through proactive maintenance and the potential costs associated with maintaining the assets. This will allow for a more detailed evaluation against the alternative of decommissioning and replacing ASP2 with either Nereda® or a bespoke ASP/IFAS system.

A.47 Figure A-2 outlines the adaptive delivery pathway for Beckton. As indicated (paragraph A.46) a strategic decision around ASP2 will need to be made in AMP8. The core / preferred pathway at this stage would be the decommissioning of ASP2 and, subject to successful demonstration of the Nereda® process (AMP8), we would propose replacing ASP2 with Nereda®. Additional capacity required post Nereda® installation would be provided by a combination of IFAS and DAF (noting that an initial installation of DAF and IFAS would be required to provide the headroom to enable decommissioning to take place). As previously indicated (paragraph A.46), we do not currently have the ‘maintain ASP2’ costs at a level of granularity to allow a meaningful comparison with alternative options; as such, selection of this pathway as the core/preferred route is based on the wider benefits that Nereda® can provide (general benefits have been provided in paragraph A.12):

- Enhanced final effluent quality – Nereda® can provide enhanced removal (compared to ASP/IFAS) of phosphorus and total nitrogen. The latter is important given that there is a regulatory risk should the Beckton permit be switched from ammonia to total nitrogen in the future. The installation of Nereda® would provide some element of initial resilience to this change
- As Nereda® works best on crude sewage, the installation would remove significant pressures on the existing PSTs providing both capacity headroom and additional outage resilience
- Nereda® has self-contained final settlement tanks; the installation would therefore potentially open up the existing ASP2 FSTs for use by ASP3 providing additional final settlement headroom for ASP3 without significant additional infrastructure
- There is a growing body of evidence that the granules produced in the Nereda® process can be recycled to existing ASPs to enhance performance
- Nereda® produces a biopolymer as a by-product which has a commercial value

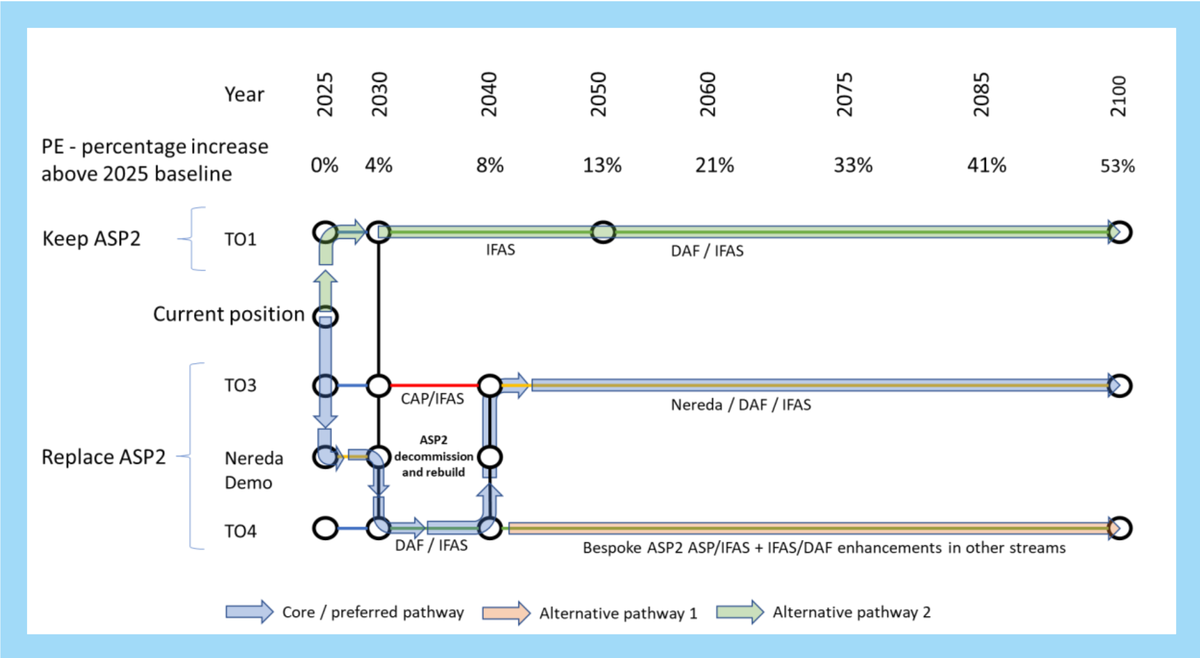


Figure A-2 Beckton STW adaptive pathway line diagram

A.48 The core/preferred pathway encompasses the following activities:

- 2025 - Investigate feasibility of Nereda®. Consideration of the installation of a demonstration Nereda® plant to confirm operational performance. Sizing any demonstration Nereda® plant such that it could provide headroom sufficient to enable adjustments to be made to the PST stream, would be beneficial
- 2030 - Start decommissioning of ASP2 and construction of new Nereda® plant. Install IFAS as a retrofit to ASP3 and replace 10% of PST flow volume with DAF to make up for treatment capacity shortfall due to ASP2 being offline (and any catchment growth between 2030-2040)
- 2035 - Replace a further 10% of PST flow volume with DAF to bring total to 20%
- 2040 - Nereda® fully commissioned and operational, replacing a further 5% of PST flow volume with DAF to bring total primary settlement to 25%

A.49 Should the feasibility study for Nereda® show the technology to be unsuitable for implementation, but the outcome of the decommissioning assessment still favours removal of ASP2, then alternative pathway 1 could be selected. This would involve replacement of ASP2 with a bespoke ASP/IFAS system as outlined in Table A-5.

A.50 If the AMP8 assessment into the decommissioning of ASP2 shows that keeping and maintaining the assets provides the most benefit, then alternative pathway 2 (Figure A-1) would be selected. The phasing of interventions is as outlined in Table A-3.

A.51 The pathway triggers can be summarised:

- In depth assessment of the cost/benefit of maintaining or decommissioning ASP2 in AMP8 – outputs will inform direction of travel to either the current core/preferred pathway (or alternative pathway 1) or alternative pathway 2
- Detailed feasibility investigations of Nereda® in AMP8 to inform direction of travel between core/preferred pathway and alternative pathway 1
- For alternative pathway 2, initial interventions would be IFAS on ASP3; the PE trigger in 2050 would require DAF to be installed and IFAS in ASP3 to be incrementally increased
- For both the core/preferred pathway and alternative pathway 1, there will be, post 2040, DAF and IFAS interventions required to address compliance risks associated with growth in population equivalent. Initially these would be based on IFAS interventions on ASP3; however, no specific triggers have been provided for increasing the levels of IFAS or the move to DAF, primarily because IFAS allows for incremental retrofits to be applied with short turnaround times which allows for an element of reactivity to the forecast materialisation of compliance risk

A.52 Post 2050, the site will be positioned to adapt to change and growth within the catchment, with the opportunities for combinations of further Nereda® expansion, additional DAFs to replace existing PSTs and additional IFAS retrofit to ASP lanes. As outlined (paragraph A.51), triggers for additional investment will be based on actual performance and forecast performance and compliance risk based on updated growth / climate change assessments.

Mogden STW

Introduction

A.53 Mogden STW is a large site, serving a catchment population of just over 2 million customers. The works is located near Heathrow and Twickenham Rugby stadium and serves eight London boroughs. Population growth in the catchment is forecast to reach close to 3 million people by 2050.

Process description

A.54 Mogden STW receives flow via three main sewers: Bath Road High-level; Chiswick; and Low-Level Sewer. The treatment process is divided into three separate streams containing batteries of ASPs, known as 'East Side Works' (Battery A & B), 'West Side Works' (Battery C) and 'West Side Extension Works' (containing Battery D & E).

- East Side Works consists of 8 PSTs, which feed 12 ASPs (6 in Battery A, 6 in Battery B), which then flow to 40 FSTs and then to the common outfall channel
- West Side Works contains 4 PSTs, 6 ASPs and 24 FSTs, which flow to the common outfall channel
- The West Side Works also includes a West Side extension which contains 12 PSTS, 7 ASPs, and 23 FSTs, which also join the common outfall channel

A.55 All flow from the works is discharged into the River Thames and flows out to the centre of the river at an island called Isleworth Ait. Of note, this is a Site of Special Scientific Interest (SSSI).

Current capacity

A.56 Mogden STW is currently receiving an upgrade to its treatment capacity through an AMP7 scheme.

A.57 Mogden's discharge permit governs both the quality of the effluent and flow limits:

- Biochemical Oxygen Demand (BOD) – 18mg/l as a 95-percentile value
- Suspended Solids (SS) – 45mg/l as a 95-percentile value
- Ammonia (AmmN) – range of 2.5mg/l to 5mg/l as a 95-percentile dependent on temperature
- Dry Weather Flow (DWF) – 559,000m3/day
- Flow to Full Treatment (FFT) – 12,315l/s

A.58 The STW is considered compliant if the effluent discharge is at or below these values. In assessing compliance risk, the BRAVA identifies that for the quality parameters, values at or below 80% of the permit are not considered a risk. Deterioration to above 80% constitutes a risk as 'headroom' has been eroded. On this basis consideration needs to be given to what options there may be to address the eroded 'headroom' and forecast when, in the absence of a solution, non-compliance might be anticipated. For DWF the risk is considered when recorded/forecast flows exceed 90% of permit value.

A.59 In general, new quality solutions will be designed such that they are at 80% of permit at the end of the planning horizon for a specific scheme. The adaptive pathway for Mogden has assumed that the basis of design for the AMP7 work will provide treatment capacity such that the works will achieve 80% of water quality permit values in the final effluent for Suspended Solids (SS), Biochemical Oxygen Demand (BOD) and Ammonia (AmmN) in the year 2040. The pre- and post-AMP7 BRAVA assessment can be seen in Figure A-3 below.

	MCAP (SS & BOD)						
	2020	2025	2030	2035	2040	2045	2050
Original BRAVA	78%	93%	95%	98%	100%	103%	107%
Post AMP7 BRAVA	71%	74%	76%	78%	80%	93%	96%

	AmmN						
	2020	2025	2030	2035	2040	2045	2050
Original BRAVA	78%	93%	95%	98%	100%	103%	107%
Post AMP7 BRAVA	71%	74%	76%	78%	80%	93%	96%

Figure A-3 Baseline Mogden STW BRAVA assessment giving pre- and post-AMP7 outputs

A.60 As shown by the BRAVA metrics, both MCAP (BOD and SS) and AmmN become at risk of exceeding permit in 2045. Based on the post-AMP7 BRAVA, and an updated assessment of future growth dry weather flow, there is no immediate (short/medium term) requirement for options to be developed. However, given stakeholder concerns on the potential for expansion of Mogden STW (through to a 2100 planning horizon), a range of strategic opportunities have been assessed, with a view to determining the extent to which they can manage any potential future capacity shortfalls.

Strategy

A.61 Ammonia removal presents the most complex challenge and, as such, has been the focus of the adaptive approach. Issues associated with BOD and SS are predominantly managed in the primary treatment and final settlement stages and are more straightforward to deal with (through provision of additional 'standard' treatment capacity) and are therefore not considered as being primary drivers for a change in pathway.

A.62 In developing our plan, we have considered compliance to 2100 to ensure that the options identified to meet compliance to 2050 are robust and support the treatment strategy to 2100, accepting there will be significant uncertainty in forecasting out to this design horizon.

Considered options

A.63 Table A-6 below summarises the option types considered to increase treatment capacity to meet capacity shortfalls.

Existing process enhancement

A.64 As for Beckton STW, the risks associated with chemical dosing in respect of operational cost, storage requirements and security of supply, have discounted this as an option for further evaluation.

Advanced primary treatment (DAF)

A.65 The option involves the replacement of existing PSTs with DAF plants.

A.66 Installation of DAF to achieve 60% BOD removal allows Mixed Liquor Suspended Solids (MLSS) reduction to 2500 mg/l across site to improve MCAP and still be sufficient to allow required nitrification. Figure A-4 below demonstrates that installation of DAF units would achieve an MCAP permit compliance of 68% in 2050.

A.67 Figure A-5 shows that installation of DAF would achieve an AmmN compliance of 46% of permit value in 2050, providing significant headroom.

	MCAP (TSS & BOD)						
	2021	2025	2030	2035	2040	2045	2050
Post AMP7 BRAVA	71%	74%	76%	78%	80%	93%	96%
DAF primary	68%	68%	68%	68%	68%	68%	68%

Figure A-4 DAF option - forecast MCAP permit exceedance over planning horizon

	AmmN						
	2021	2025	2030	2035	2040	2045	2050
Post AMP7 BRAVA	71%	74%	76%	78%	80%	93%	96%
DAF primary	26%	30%	32%	34%	37%	41%	46%

Figure A-5 DAF option - forecast AmmN permit exceedance over planning horizon

Option type	Option description
Existing Process Enhancement	Following on from work undertaken as part of the PR19 process, the following technical options were considered for DWMP inclusion: To address MCAP exceedances: - Chemical Aided Precipitation (CAP) at PSTs/FSTs - DAF as a replacement for existing PSTs - Additional FSTs - Rectangular Clarifiers instead of circular FSTs. To address AmmN exceedances: - IFAS - DAF as a replacement for existing PSTs
Construct New / Additional STWs	This option involves developing a new STW on a site near to Heathrow to take all flows currently transferred to Mogden. The primary option constraint is the requirement for a new discharge location. The nearest watercourse is the River Crane, but this is a stressed watercourse with strong stakeholder interest. The assessment considered that the likelihood of a new permit being granted would, given the likely stakeholder challenge, be very low. On this basis, the option was not considered further in any detail.
Water Resources Management Plan (WRMP) - Hydes Field	This WRMP option has been developed as a potential mechanism to help address supply demand deficits in potable water supply in the London area. The option involves the transfer of raw sewage from our Mogden South Sewer to an Advanced Wastewater Recycling Plant (AWRP) to be located at Hydes Field, where it will be treated to a high standard (biological treatment combined with reverse osmosis (RO) and ultra-violet oxidation) and the effluent discharged to the River Thames upstream of our Walton potable water abstraction. In the current proposed design, the waste streams will be fed back to Mogden. Biological components (from primary and secondary treatments) would be returned to the main sewer for treatment at Mogden STW, whilst the saline waste stream from the RO process would be returned and discharged directly at the Mogden STW outfall without further treatment. Key DWMP assumptions: • The WRMP scheme is proposed at 50Ml/d – previous work has identified that 59.7Ml/d raw sewage flow would be required to meet the 50Ml/d treated effluent flow. • Scheme will operate continuously – further work would be required on this element. For many WRMP schemes involving indirect reuse, operation may only be required under severe drought conditions. Operated in such a manner, the available benefits to the STW would be limited. • The assessment undertaken has considered the current waste stream management (returns to Mogden) and an alternative, whereby the waste streams, excluding RO wastes, are treated at Hydes Field. The need for the scheme is very much driven by WRMP requirements as opposed to those identified in the DWMP (noting that from the BRAVA any benefits would not be required under the DWMP until 2045 at the earliest).
Wild Card - Iver South	Sludge produced at Mogden is currently subjected to pasteurisation and conventional anaerobic digestion on site at Mogden and the digested sludge transferred to Iver South sludge treatment centre for dewatering. The liquors from the dewatering process are currently returned to the Mogden STW inlet and contain a significant ammonia load. There is a proposal to upgrade the sludge treatment in AMP8 to an advanced digestion process utilising thermal hydrolysis (THP). The process enhances solids destruction and increases the amount of available biogas; however, it has the disadvantage in that the ammonia loads are significantly increased in dewatering returns. To counter this, the AMP8 proposal includes for ammonia recovery to be installed on the Iver South site. In addition to providing a commercial opportunity for the recovered ammonia, the process will reduce the ammonia load returning to the Mogden inlet providing a material capacity benefit.

Table A-6 Summary of treatment options included in the DWMP assessment for Mogden STW

Advanced secondary treatment (IFAS)

A.68 This option considers the retrofitting of IFAS to existing ASP lanes in blocks C, D and E (the limit reflects potential concerns over the structural integrity of blocks A and B to accept any retrofit) to increase biological treatment capacity.

A.69 Installation of IFAS for 30% of the aeration lane volume with a 40% media fill in the IFAS zone would increase AmmN removal capacity. Figure A-6 below demonstrates that installation of IFAS as per the above specification would achieve an AmmN permit compliance of 78% in 2050.

A.70 Extrapolating forward assuming a linear deterioration in performance as a function of growth, the IFAS installation as outlined would provide an additional 15 years of headroom (to 90% of permit in 2065) with failure at 100% of permit in 30 years (2080).

A.71 It should be noted that further investigation of IFAS for potential application to blocks A and B will be considered in the next cycle of the DWMP given the increasing range of alternative IFAS technologies that are available. If feasible, this would provide additional capacity headroom above and beyond that provided by the block C, D and E installations.

	AmmN						
	2021	2025	2030	2035	2040	2045	2050
Post AMP7 BRAVA	71%	74%	76%	78%	80%	93%	96%
IFAS	21%	27%	30%	37%	45%	68%	78%

Figure A-6 IFAS option - forecast MCAP permit exceedance over planning horizon

Combined impact of DAF/IFAS

A.72 The potential benefits identified for DAF and IFAS in isolation have been outlined. Combinations of DAF and IFAS have the potential to significantly extend the operational capacity of the works. Figure A-7 shows a matrix based on a limited combination set (DAF on blocks A and B, IFAS on blocks C, D and E) which shows that combining interventions can significantly enhance the available headroom (determined from the percentage of permit capacity identified at 2051).

2051 scenario AmmN					
% DAF lane blocks A&B only	IFAS % lane volume % media fill (lane blocks C,D E only)				
	0	10 20	10 40	30 20	30 40
75%	84%	37%	29%	21%	17%
50%	94%	49%	40%	32%	28%
25%	108%	65%	57%	48%	45%
0%	124%	98%	90%	82%	70%

Figure A-7 DAF and IFAS intervention matrix

Clarifier upgrades

A.73 This option considers the conversion of existing circular final effluent clarifiers to rectangular clarifiers.

A.74 Upgrades to existing clarifiers allow the ASP to carry higher MLSS and so help to resolve MCAP and AmmN constraints. Rectangular clarifiers occupy the same footprint as existing circular units but use space more efficiently, providing a 50% increase in settlement area.

Rectangular clarifiers were modelled for batteries A,B,C and D only (not E) and the results are shown below. An example scope would include 38 rectangular units (41m x 20m) to replace 76 existing circular units.

A.75 Figure A-8 shows that upgrading the clarifiers would achieve 54% of the MCAP permit value in 2050, and Figure A-9 provides the forecasted ammonia permit value of 74% in 2050.

	MCAP (TSS & BOD)						
	2021	2026	2031	2036	2041	2046	2051
Post AMP7 BRAVA	71%	74%	76%	78%	80%	93%	96%
Rectangular clarifiers	49%	49%	49%	49%	54%	54%	54%

Figure A-8 Clarifier upgrade option - forecast MCAP permit exceedance over planning horizon

	AmmN						
	2021	2026	2031	2036	2041	2046	2051
Post AMP7 BRAVA	71%	74%	76%	78%	80%	93%	96%
Rectangular clarifiers	48%	53%	60%	67%	58%	66%	74%

Figure A-9 Clarifier upgrade option - forecast AmmN permit exceedance over planning horizon

WRMP - Hydes Field

A.76 As part of the WRMP, a proposed new advanced STW would be built at Hydes Field, abstracting from our South Sewer (one of several feeds to Mogden STW), to provide additional resource to the River Thames for abstraction at Walton WTW for public water supply. This will generate additional sludge and concentrate from the treatment process.

A.77 Two sub-options have been considered for treatment of the resulting sludge from the new works:

- Return of sludge streams arising on site back into the sewer
- Full sludge treatment on site

A.78 In both cases the concentrate would be returned to Mogden STW, which reduces the impact on DWF from 50 MLD abstracted from our South Sewer to 40.1 (with sludge return) or 41.1 MLD (with sludge treatment).

A.79 The impact of this option is significant on DWF and on AmmN headroom for Mogden STW, but small for MCAP.

A.80 Figure A-10 and Figure A-11 show the headroom gain by implementing this option based on growth forecasts for flow and population.

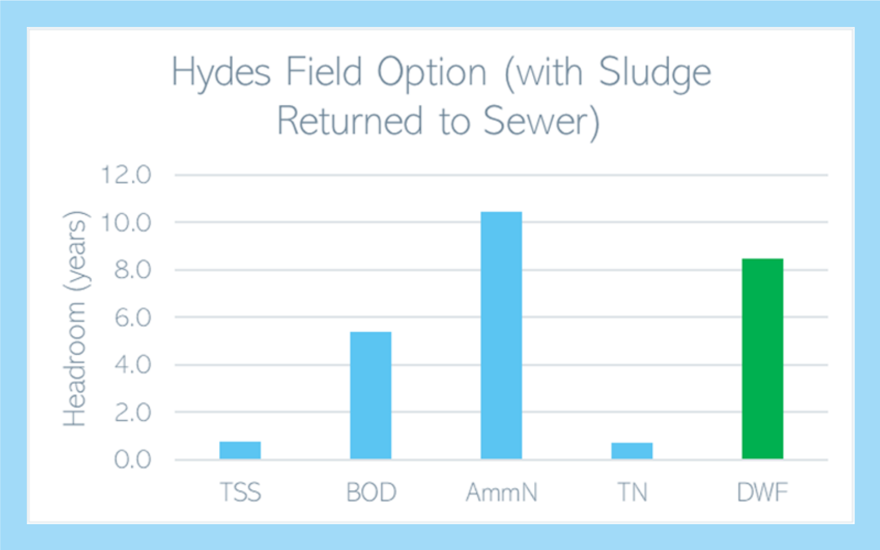


Figure A-10 Hydes Field option headroom (with sludge returned to sewer)

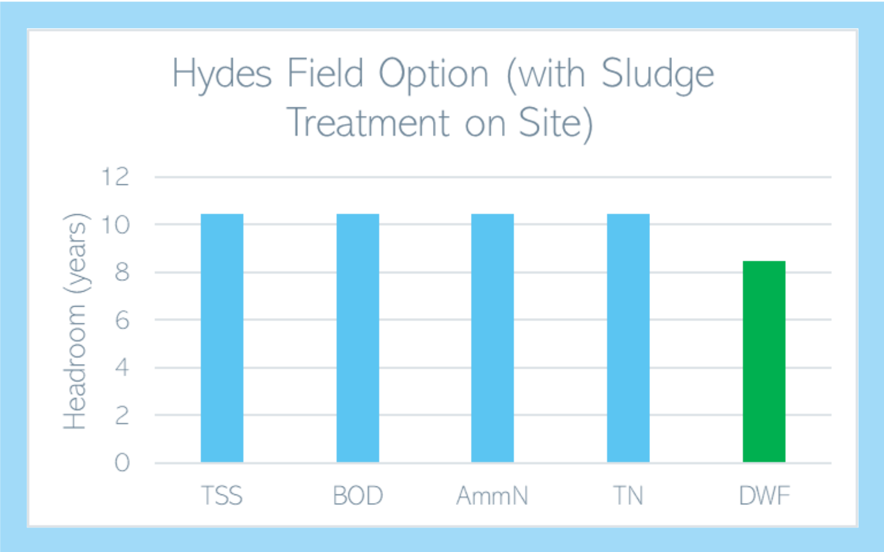


Figure A-11 Hydes Field option headroom (with sludge treatment on site)

Wild Card - Iver South Liquor Treatment Plant

A.81 The upgrade of the sludge treatment process at Mogden STW to advanced digestion using thermal hydrolysis, is planned for AMP8. Alongside this, it is proposed that an ammonia recovery plant be installed at Iver South. This would have the benefit of a significant reduction in the ammonia load being returned to Mogden STW.

A.82 Modelling for this option has been undertaken and assumes a 90% reduction in AmmN load returned from Iver South to West side works (C, D and E batteries). This option has no impact on Dry Weather Flow (DWF) to Mogden STW.

A.83 As shown in Figure A-12, installation of a Liquor Treatment Plant (LTP) at Iver South would result in a forecast 96% of MCAP permit in 2050 (i.e., no change from baseline).

A.84 Figure A-13 shows that AmmN exceedance of 96% (baseline) is reduced to 92% of permit in 2050 through installation of LTP at Iver South. This reduction alone does not allow for sufficient headroom in forecasted permit exceedance and would therefore need to be complimented by another option to mitigate against risk of permit exceedance.

	MCAP (TSS & BOD)						
	2021	2025	2030	2035	2040	2045	2050
Post AMP7 BRAVA	71%	74%	76%	78%	80%	93%	96%
Liquor treatment	71%	74%	76%	78%	80%	93%	96%

Figure A-12 Iver South LTP - forecast MCAP permit exceedance over planning horizon

	AmmN						
	2021	2025	2030	2035	2040	2045	2050
Post AMP7 BRAVA	71%	74%	76%	78%	80%	93%	96%
Liquor treatment	42%	49%	61%	67%	75%	83%	92%

Figure A-13 Iver South LTP - forecast t AmmN permit exceedance over planning horizon

Our core and alternative pathways for Mogden STW

A.85 The DWMP assessment has assumed that the AMP7 improvements at Mogden STW will provide headroom to 2040.

A.86 The core pathway assumes a combination of offsite liquor treatment (Wild card - Iver South proposed for AMP8 as part of our bioresources strategy), the indirect reuse scheme at Hydes Field, and a combination of DAF/IFAS upgrades on the current Mogden STW site. In combination, this will provide capacity through to the end of the current planning horizon (2050) and opportunities for maintaining resilience at the site through to 2100.

A.87 The primary uncertainty is the WRMP derived need for the indirect reuse scheme and in particular, the benefits from continuous operation as opposed to drought only operation. The options assessment has shown that if the WRMP scheme is delayed, or if operation on a continuous basis is not considered feasible (given high energy requirements of the RO element this could be a significant disadvantage), then alternative pathways involving DAF / IFAS either alone or in combination can be adopted to maintain the work's compliance.

A.88 Figure A-14 shows that this core pathway can be adapted. If the WRMP scheme is delayed but the liquor treatment plant at Iver South is progressed as part of our bioresources strategy in AMP8, then alternative pathway 1 can be selected. This pathway would involve initial installation of IFAS up to its maximum capacity (flexible installation as a function of actual and forecast exceedance); based on modelling undertaken, and assumed PE increases beyond 2050, DAF installations would be required from 2075 to maintain compliance with thresholds. If neither the WRMP scheme nor the liquor treatment plant at Iver South are progressed, then alternative pathway 2 can be selected. This will involve installation of IFAS (flexible installation as for alternative pathway 1) with DAF as required from 2060.

A.89 In all cases, the triggers for change will be a function of a continuous assessment of compliance risk (based on actual performance and forecast performance utilising updated system inputs) coupled to an understanding of the beneficial impacts of the strategic schemes (WRMP and Iver South liquor treatment) as and when implemented.

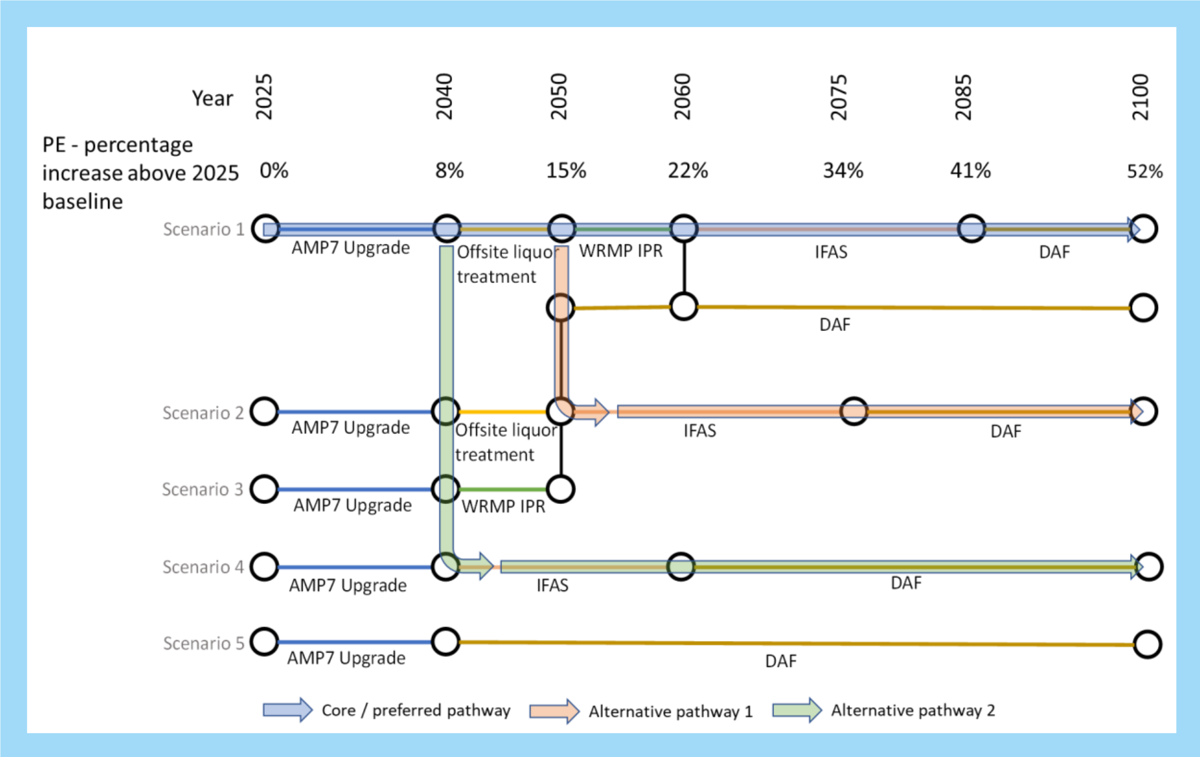


Figure A-14 Mogden STW adaptive pathway line diagram

Navigating our DWMP

We've developed a comprehensive document suite to share our final DWMP. This includes five summary documents that contain increasing levels of detail. To help you to navigate around our document suite and to find key DWMP content, we provide a Navigation index below and on our DWMP webpage. The orange cells refer to where key DWMP content can be found across our final document suite.

	Navigation index	**Protecting the environment and providing a reliable, sustainable wastewater service**							**Best value and delivery**					**Working together**		**DWMP stages and data**				
		Storm overflows	Sewer flooding	Level of ambition & pace of delivery	Growth & climate change	Resilience: flooding & power	Groundwater	Environmental assessments	Affordability & bill impact	Best Value	Base vs Enhancement	Solutions & deliverability	Programme alignment	Partnership working	Stakeholder & customer engagement	DWMP stages & process	Level 2 regional summaries	Level 3 regional summaries	Data tables	Risk & Assurance
Summary documents	Customer summary	■	■											■	■	■				
	Non-technical summary	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■				
	Technical summary	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■				
	The Plan	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■				
	Catchment Strategic Plans x13	■	■	■	■	■	■	■	■	■	■	■	■	■	■		■	■		
Technical appendices x11	Appendix A - Strategic context												■			■				
	Appendix B - Risk-Based catchment screening															■				
	Appendix C - Baseline risk and Vulnerability assessment				■	■										■				
	Appendix D - Options development and appraisal	■										■				■				
	Appendix E - Programme appraisal	■		■		■			■	■	■	■	■			■				
	Appendix F - Stakeholder engagement														■	■				
	Appendix G - Adaptive pathway planning	■	■		■															
	Appendix H – Customer engagement Part A – Draft DWMP														■	■				
	Appendix I - Risk and uncertainty											■								■
	Appendix J - DWMP and WRMP alignment												■							
	Appendix M - Assurance																			■
New technical appendices x9	Appendix N - You Said, We Did (YSWD)	■	■	■	■	■	■	■	■	■	■	■	■	■	■					
	Appendix O - What base buys										■									
	Appendix P - Response to July 2021 Floods		■	■	■	■			■			■	■	■	■					
	Appendix Q - Storm overflows	■		■	■				■				■							
	Appendix R - Delivery of SuDS and nature-based solutions	■	■	■	■	■			■	■		■	■	■	■					
	Appendix S - Partnership opportunities and working			■								■		■	■					
	Appendix T - Groundwater quality						■													
	Appendix U - Resilience		■		■	■							■	■	■					
	Appendix V – Customer engagement Part B – Consultation Survey Report														■					
Environmental assessments	Appendix K - Strategic environmental assessment (SEA)							■												
	Appendix L - Habitats regulations assessment (HRA)							■												
Portals and data	Customer portal	■	■							■		■		■	■	■	■	■		
	Practitioner portal	■	■											■	■		■	■		
	Data tables			■							■								■	
	Data tables commentary																		■	

We welcome your views on our DWMP. Please share them with us by emailing:
DWMP@thameswater.co.uk.

This document reflects our DWMP 2025-2050 as published in May 2023.