



TMS21 Enhancement Case: Reducing the Risk of Basement Flooding

Contents

| | |
|---|----|
| 1. Description of the proposed enhancement | 5 |
| 2. Need for enhancement investment | 11 |
| We must deliver a step change in the risk of customers' basements flooding | 12 |
| Customers and stakeholders consider addressing basement flooding risk is a priority | 22 |
| This enhancement does not overlap with base or previously funded projects | 29 |
| We start protecting the highest risk basement properties in AMP8 | 31 |
| 3. Best option for customers | 34 |
| Options assessment for site solutions | 37 |
| Customer and stakeholder engagement | 37 |
| Selection of high-risk sites and solution development | 38 |
| 4. Cost efficiency | 45 |
| How we have developed our costs for this case | 46 |
| How we have challenged our proposed costs | 46 |
| Our proposed costs | 47 |
| Our approach to determining cost efficiency | 48 |
| Considerations Ofwat should make when determining our cost efficiency | 49 |
| 5. Customer protection | 52 |
| 6. Adaptive planning | 55 |
| Annex B – Case study on response times to major bursts | 71 |

Summary Table

Table 1: Summary Table

| Reference | PR24 Enhancement Case – Reducing the risk of basement flooding |
|-------------|---|
| Description | <p>To meet our 2050 Vision and always maintain a reliable supply, we need to mitigate the risk of flooding to basement properties in the event of a failure from our trunk mains network.</p> <p>Trunk main assets located close to, and in the most extreme circumstances within basement properties, pose a serious risk to life. Entire basements can be flooded within seconds of failure of one of these pipes. Additionally, building foundations can be compromised and severe structural damage caused by the explosive nature of bursts. We have identified the highest risk locations, (all located in London), where failures pose a risk of rapid basement flooding, putting the lives of our customers at risk. Schemes have been prioritised based upon the number of basements at risk of flooding and the likelihood of failure of the associated water mains. Our externally verified trunk main risk model has guided the selection of schemes, with the final selection criteria supplemented by operational input.</p> <p>We are unable to adopt a reactive repair approach to trunk mains near or within basements because water in these mains is under high pressure and high flow, failures can flood a basement property within seconds, far faster than we would be able to attend site and isolate the main. If individuals are unable to evacuate in time or become trapped, there is a very real risk to life.</p> <p>Our analysis concludes that we simply cannot respond quickly enough by proactive monitoring or other operational techniques to mitigate this safety risk to customers.</p> <p>The sites selected for delivery in AMP8 are the highest risk locations across our network, where the likelihood of failure and number of basements affected is the greatest. We have included within this submission the top 20 prioritised sites, from which we currently expect to deliver 10 schemes totalling 12km. We expect deliverability constraints such as road access to inform which schemes will be deliverable from the top 20 sites during AMP8, with the remainder to be prioritised for AMP9.</p> <p>This activity is separate from our base trunk main management programme included within our botex allowance, which typically comprises large numbers of lower cost interventions including valve maintenance and installation, enhanced inspection and monitoring capabilities, as well as reactive repair work to improve interruptions to supply, leakage and mains bursts performance. Higher cost, proactive trunk main replacement activity has instead historically been funded through shareholder contributions during AMP6 (£96 million) and AMP7 which are over and above the Final Determination allowance.</p> <p>The trunk main rehabilitation schemes currently in delivery during AMP7 under the London Water Improvement Conditional Allowance (LWICA) do provide an element of basement flooding benefit and this Enhancement Case also proposes £46m to complete the schemes started under the LWICA in AMP7 at the start of AMP8. However, the LWICA schemes were prioritised</p> |

| | |
|----------------------------|--|
| | |
| | <p>based upon a holistic view of trunk main risk, which incorporates additional risk factors such as supply interruptions, traffic disruption and leakage, rather than focusing solely upon the risk of basement flooding. The benefit to almost 2,000 basement properties delivered through the AMP7 LWICA trunk main rehabilitation schemes was not the main prioritising factor for this work.</p> <p>The core focus of our AMP8 Enhancement Case is entirely on the risk of basement flooding from our trunk mains network. We are reducing the safety risk for a discrete number of customers. We believe the level of work we are proposing to undertake during AMP8 to be deliverable and low regrets. Under our core pathway we expect the cost of rehabilitation to reduce in the future and to develop long-length condition assessment technology which will enable us to rationalise the scope of work under each rehabilitation scheme. We therefore plan to be able to deliver a greater volume of work, with higher confidence and greater efficiency in future AMPs. We consider our approach balances the long-term need to protect all customers in a basement property with unacceptable risk by 2050 with the short-term objective of protecting the customers at greatest risk.</p> <p>We heard overwhelming support from customers and stakeholders that mitigating this risk needs to be prioritised within our investment plans. Customer research has shown that our customers also favour a 'prevention over cure' approach and unanimously support a move towards more proactive trunk main rehabilitation.</p> |
| Outputs | <p>We will rehabilitate 12km of trunk mains which will benefit over 4,000 basement properties identified as being at the highest risk of flooding from a failure of our trunk main network.</p> <p>To protect customers from any potential under-delivery, we propose a PCD of 'km of main rehabilitated'. We believe 'km of main rehabilitated' will be a straightforward measure for our customers to understand and that we can be held account to easily.</p> <p>We will also deliver an additional 1.1km of mains rehabilitation to complete the London Water Improvement Conditional Allowance AMP7 schemes. This will be managed under the existing customer protection mechanism for the conditional allowance.</p> |
| Cost | <p>£170m capex (22/23) to deliver 12km of trunk main rehabilitation to reduce the risk of basement flooding.</p> <p>£46m capex (22/23) to complete London Water Improvement Conditional Allowance AMP7 schemes in 2022/23 prices</p> <p>Total: £216m (2022/23)</p> |
| Spend apportionment | <p>This investment sits 100% within the Water Network Plus price control.</p> <p>Our Long-Term Delivery Strategy sets an ambition of fully mitigating the risk of basements flooding by 2050. We forecast that we will deliver 6% of this programme in AMP8 – we consider that this is an appropriate low regrets next step along our core pathway, which balances an immediate prioritised risk reduction for customers with delivering more cost-effectively in the future, as more innovative no dig or low-dig rehabilitation techniques become possible.</p> |

| | <p>The cost split across AMPs for our plan to reduce basement flood risk (AMP7 LWICA carryover in AMP8) is as follows:</p> <table border="1"> <thead> <tr> <th>AMP</th> <th>Cost £m</th> <th>% Total Spend to 2050</th> </tr> </thead> <tbody> <tr> <td>8</td> <td>170 (216)</td> <td>6</td> </tr> <tr> <td>9</td> <td>398</td> <td>14</td> </tr> <tr> <td>10</td> <td>558</td> <td>20</td> </tr> <tr> <td>11</td> <td>761</td> <td>27</td> </tr> <tr> <td>12</td> <td>940</td> <td>33</td> </tr> <tr> <td>Total</td> <td>2,828 (2,874)</td> <td>100</td> </tr> </tbody> </table> | AMP | Cost £m | % Total Spend to 2050 | 8 | 170 (216) | 6 | 9 | 398 | 14 | 10 | 558 | 20 | 11 | 761 | 27 | 12 | 940 | 33 | Total | 2,828 (2,874) | 100 |
|----------------------|--|-----------------------|---------|-----------------------|---|-----------|---|---|-----|----|----|-----|----|----|-----|----|----|-----|----|--------------|----------------------|------------|
| AMP | Cost £m | % Total Spend to 2050 | | | | | | | | | | | | | | | | | | | | |
| 8 | 170 (216) | 6 | | | | | | | | | | | | | | | | | | | | |
| 9 | 398 | 14 | | | | | | | | | | | | | | | | | | | | |
| 10 | 558 | 20 | | | | | | | | | | | | | | | | | | | | |
| 11 | 761 | 27 | | | | | | | | | | | | | | | | | | | | |
| 12 | 940 | 33 | | | | | | | | | | | | | | | | | | | | |
| Total | 2,828 (2,874) | 100 | | | | | | | | | | | | | | | | | | | | |
| Delivery year | 12 km cumulative target will be delivered by April 2030. | | | | | | | | | | | | | | | | | | | | | |
| DPC | The case has been assessed as not being suitable, as the construction and operations and maintenance risks could not be passed to a Competitively Appointed Provider (CAP). For more information, please refer to TMS38 Direct Procurement for Customers. | | | | | | | | | | | | | | | | | | | | | |

1. Description of the proposed enhancement

- 2.1. This Enhancement Case reduces the risk of a potential customer fatality arising from the rapid flooding of a basement property in the event of a network failure at over 4,000 of the highest risk basement properties across our London network. We will reduce this risk in AMP8 through a targeted £170 million programme of rehabilitation to replace or slip-line trunk mains. Our options analysis found these are the only methods that can appropriately mitigate this risk.
- 2.2. We also include £46m capex to complete the schemes started in AMP7 under the London Water Improvement Conditional Allowance, which proactively targets the highest risk mains across our network in AMP7. The remainder of the work proposed under this Enhancement Case will continue to build on the work delivered under LWICA during AMP7/ the start of AMP8 and will continue to implement lessons learned from the delivery of these schemes. We note that the LWICA investment will be ringfenced from the rest of

our programme and has its own customer protection mechanisms that were agreed with Ofwat following Stage Gate 4 of the conditional allowance submission in August 2022¹.

- 2.3. Our externally verified trunk main risk model has guided the selection of schemes to reduce basement flooding risk, with the final selection criteria supplemented by operational input. This model has been subject to several independent reviews, most recently by Isle Utilities in 2021² which recognised ‘the extent, sophistication, and extreme maturity of the current Trunk Mains Risk Model, as observed by Isle’s experienced asset management consultants through the exercise, which indicates the model is leading practice compared to industry norms. Additionally, in comparison to the international risk modelling practices, Thames Water’s TM Risk Modelling, aligns well with Australian and US utility practices (many who are deemed leading practice), whilst exceeding utility practice maturity when compared to available examples in the UK and Asia’.
- 2.4. This is the same tool used to prioritise work under the LWICA, presented to Ofwat as part of Stage Gate 2 of the conditional allowance³.
- 2.5. We have used flood inundation modelling to map basement properties that are at risk of flooding from a burst on our trunk main network and then prioritised parts of our network where the risk of rapid basement flooding following a burst event applies to the greatest number of properties and where the likelihood of a trunk main failure occurring is highest i.e. where we estimate asset condition to be most deteriorated.
- 2.6. The comprehensive basement dataset has been compiled from three sources (PR09 basement data, Verisk basement data and OS Address Base Premium dataset) which has given us the most complete basement dataset ever used by Thames Water. This data was last updated in 2018. In addition, an extensive number of manual updates have been made from visual checks (desk-based study using Google Maps and feedback from field staff).
- 2.7. Our probability of trunk main failure model includes all trunk main materials and incorporates 20 years of research into cast iron pipes by Thames Water and the University of Surrey. It comprises a series of individual models targeted at different materials and uses a combination of engineering principles, statistical techniques and machine learning to give material-specific deterioration rates and the capacity to incorporate asset condition data from non-destructive testing of mains.
- 2.8. We recognise that there is a high health and safety risk from rapid flooding associated with 37,545 basement properties within our network due to the proximity of 343km of trunk mains. Our long-term goal to 2050 is to mitigate the safety risk associated with our assets for all these basement properties. We are, however, cognisant of the current cost of rehabilitation of some of our largest trunk main assets and the limitations of current

¹ LWI-G4-A2 Shareholder Contribution Guarantee and Customer Protection Mechanism (August 2022)

² Isle (2021) Thames Water Trunk main Risk Modelling Strategic Review

³ LWI.G2.C1 – Trunk Mains Decision Making Methodology (December 2021).

condition assessment technology, which is not suitable for long lengths of main; only spot values. We assume both to improve under our Best Value Pathway in future AMPs.

- 2.9. For AMP8, our investment will address the most critical sections of trunk main, which pose a risk to the largest number of basement properties and carry the highest likelihood of failure, all of which are all located in London.

Table 2: Our proposed AMP8 investment (£m 2022-23)

| | 2025/26 | 2026/27 | 2027/28 | 2028/29 | 2029-30 | AMP8 |
|---------------------------------|---------|---------|---------|---------|---------|-------|
| Basement Risk Trunk Mains Totex | 0 | 25.8 | 60.9 | 41.6 | 41.8 | 170.1 |
| LWICA Carryover | 45.6 | 0.7 | 0.1 | 0 | 0 | 46.3 |

Source: Thames Water

- 2.10. Our approach for reducing the risk of basement property flooding is not part of the activities in our botex trunk mains management programme. Our botex programme comprises large numbers of lower cost interventions including valve maintenance and installation, enhanced inspection and monitoring capabilities, as well as reactive repair work to improve interruptions to supply, leakage and mains bursts performance. The programme takes a holistic view of risk, looking at several other factors as well, such as customers at risk of receiving low pressures and traffic disruption, in addition to flooding impact. Planned trunk main replacement activity has instead historically been funded through shareholder contributions during AMP6 (£96m) and AMP7, which are over and above the Final Determination allowance.
- 2.11. This Enhancement Case focuses solely on the risk to life from rapid basement flooding following a trunk main failure, which we are now more accurately able to assess following a recent step-change in our modelling capability to transition to advanced flood modelling. We believe the risk to life resulting from a failure of these assets so severe in relation to basement properties, that we must valorise investment without considering the other serviceability factors considered under our botex programme and look to intervene prior to experiencing a severe asset failure. We have selected our AMP8 scope based on our customers' preferences across all of our proposed enhancement, while balancing cost and deliverability.
- 2.12. A list of top 20 basement risks across our network is detailed in Table 3: AMP8 proposed schemes (long list) below. The list is separated into 10 schemes that we are proposing to deliver under this Enhancement Case during AMP8, the LWICA carry over included within this Enhancement Case, and the remaining schemes which we will substitute in should there be deliverability constraints (such as road access) that would mean we would be unable to deliver a scheme within the AMP. Where new failure or operational data may lead to a change in the prioritisation of schemes delivered, any substitutions will be from the 343km of trunk main which carry basement flooding risk.
- 2.13. Costs for schemes have been estimated based upon a unit rate for the average cost of six trunk main rehabilitation schemes which are either in delivery during AMP7 or have

undergone extensive cost assurance already. The schemes used in this costing exercise represented a range of pipe diameters, site circumstances and a blend of solution types (slip lining and open cut). We expect this to be representative of the programme we will deliver in AMP8.

- 2.14. At a programme level we expect this to be an efficient but challenging programme to deliver 12km for £170m.
- 2.15. The list has been prioritised on basement flood risk, which accounts for the number of basements per metre of main, and the likelihood of asset failure of that trunk main. We show a worked example below the table.
- 2.16. Although the list has not been prioritised based upon a cost benefit analysis, given the potential consequence of failure at our highest risk sites, we also provide an assessment of the cost benefit in terms of basement risk reduction per £m to demonstrate value for money.

Table 3: AMP8 proposed schemes (long list)

| | No. | Location | Length (m) | Basement no. | Estimated Cost Including D&PG | Current Basement Risk | Basement Risk Post Intervention | CBA: Basement Risk Reduction per £m |
|-----------------------|-----|--|------------|--------------|-------------------------------|-----------------------|---------------------------------|-------------------------------------|
| AMP8 Proposed Schemes | 1 | ██████████ ██████████ | 955 | 823 | £13.8 m | 0.1451 | 0.0008 | 0.0105 |
| | 2 | ██████████ ██████████ | 1185 | 285 | £17.1 m | 0.0911 | 0.0029 | 0.0051 |
| | 3 | ██████████ | 1374 | 159 | £19.9 m | 0.0744 | 0.0013 | 0.0037 |
| | 4 | ██████████ ██████████ | 1167 | 242 | £16.9m | 0.0646 | 0.0004 | 0.0038 |
| | 5 | ██████████ ██████████ ██████████ ██████████ ██████████ | 969 | 200 | £14 m | 0.0572 | 0.0010 | 0.0040 |
| | 6 | ██████████ ██████████ ██████████ | 2042 | 427 | £29.6 m | 0.0557 | 0.0011 | 0.0018 |
| | 7a | ██████████ ██████████ ██████████ | 842 | 653 | £22.9 m | 0.0550 | 0.0011 | 0.0044 |

| | No. | Location | Length (m) | Basement no. | Estimated Cost Including D&PG | Current Basement Risk | Basement Risk Post Intervention | CBA: Basement Risk Reduction per £m |
|-----------------|---------|----------------------|------------|--------------|-------------------------------|-----------------------|---------------------------------|-------------------------------------|
| | 7b | ██████ | 740 | | | 0.0543 | 0.0011 | 0.0050 |
| | 8 | ██████████ | 607 | 396 | £8.9 m | 0.0529 | 0.0007 | 0.0059 |
| | 9 | ██ ██████ | 507 | 302 | £7.4 m | 0.0493 | 0.0006 | 0.0066 |
| | 10a | ██████ ██████ | 1058 | 547 | £26.3 m | 0.0124 | 0.0028 | 0.0007 |
| | 10b | ██████ ██████ | 762 | 120 | | 0.0022 | 0.0004 | 0.0002 |
| | 11 & 12 | ██████ ██████ ██████ | 1090 | N/A | £46.3 m | N/A | N/A | N/A |
| Back-up schemes | 13 | ██████ ██████ | 878 | 541 | £12.8 m | 0.1962 | 0.0001 | 0.0154 |
| | 14 | ██████████ | 481 | 157 | £7 m | 0.0546 | 0.0021 | 0.0075 |
| | 15 | ██████████ | 656 | 170 | £9.5 m | 0.0885 | 0.0006 | 0.0092 |
| | 16 | ██ ██████ | 838 | 243 | £12.2 m | 0.0662 | 0.0012 | 0.0053 |
| | 17 | ██████████ | 975 | 322 | £14.1 m | 0.0639 | 0.0020 | 0.0044 |
| | 18 | ██████████ | 732 | 456 | £10.6 m | 0.0607 | 0.0001 | 0.0057 |
| | 19 | ██████ ██████ | 424 | 275 | £6.1 m | 0.0863 | 0.0001 | 0.0141 |
| | 20 | ██████████ | 468 | 174 | £6.8 m | 0.0544 | 0.0000 | 0.0080 |

Source: Thames Water

- 2.17. In order to demonstrate the nature of our analysis we have included a worked example of our highest risk scheme in Table 4 detailed below. This replicates the data in our trunk main risk model.
- 2.18. The Trunk Main Risk model is held in Asset Investment Manager (AIM), developed by Probit Consulting. AIM calculates risk for ~123,000 Simulated Burst Points across the trunk main network. Basement risk has been calculated using the consequence of failure associated with the simulated burst point, from flood inundation modelling, and the likelihood of failure of that main, derived from a combination of statistical modelling, engineering models and historical failures.
- 2.19. In the example below, AIM has multiplied the number of basements potentially impacted by a failure at burst point '2206519_1', multiplied by an annual failure probability of 0.0147 and divided by the Simulated Burst Length (length associated with the burst point) to give a basement risk per meter of 0.145.
- 2.20. As AIM uses 'Superstrings' to aggregate connecting mains, the maximum basement risk calculated for a simulated burst point within any superstring was applied to the entire superstring to ensure that 'worst-case' basement risk is prioritised. The overall benefit of intervention of the superstring is then given as the sum of basements protected by reducing the likelihood of failure at all simulated burst points within the superstring.

Table 4: [REDACTED] Basement Risk worked example.

| Calculation | Basement Risk per meter = $\frac{\text{Max basements impacted by any given simulated burst point} * \text{burst frequency}}{\text{simulated burst length}}$ |
|---|--|
| Pre-intervention | [REDACTED] Basement Risk per meter = $\frac{94 * 0.0147}{9.52\text{m}} = 0.145$ |
| Post-intervention* | [REDACTED] Basement Risk per meter = $\frac{94 * 0.00009}{9.52\text{m}} = 0.0008$ |
| *Assuming modelled failure frequency of a new PE pipe | |

Source: Thames Water

- 2.21. Figure 1 shows the potential flood extent and location of 823 at-risk basement properties along the highlighted spans we propose to rehabilitate as part of this scheme. The flood modelling suggests that failures along [REDACTED] could impact as far as [REDACTED].



Source: Thames Water

2. Need for enhancement investment

- 3.1. We consider the risk of flooding for basement properties resulting from a failure of our trunk mains poses a genuine and critical risk to the health and safety of our customers. This risk is more significant if the failure occurs on our trunk main network, which provides water at higher pressure and higher flow rate than our small distribution mains, and therefore has the potential to flood basement properties much more quickly, which in the most extreme scenarios can occur in seconds.
- 3.2. If basement flooding does occur rapidly and the water level rises quickly, there is a risk to life or serious hazard. This can result from:
- Drowning - rapidly rising water levels can lead to drowning if individuals are unable to evacuate the basement in time or become trapped.
 - Electric shock - when water comes into contact with electrical systems or appliances in a flooded basement, there is an increased risk of electric shock. This can be life-threatening, as electricity can travel through the water and pose a danger to anyone in the vicinity.
 - Structural damage/collapse - in extreme cases, rapid flooding can exert significant pressure on the basement walls and foundation, potentially leading to a structural collapse.

- 3.3. In addition, flooding can also cause significant water damage to a basement and its contents. The water can saturate carpets, furniture, walls and personal belongings, leading to costly repairs or replacements.

We must deliver a step change in the risk of customers' basements flooding

- 3.4. Compared to ground-level or above-ground properties, basements are at risk of rapid inundation of enclosed spaces from which customers may find an escape challenging or not possible – especially for less mobile customers. In the most extreme scenario, the rapid inundation of such properties could result in fatalities.
- 3.5. Trunk main assets located close to, and in the most extreme circumstances within, basement properties pose a serious risk to life. Figure 2 below shows three large trunk mains within a basement [REDACTED] in London. Should one of these mains fail catastrophically within the basement, the basement would be flooded in seconds, and there is a high likelihood of structural damage being caused. The mains highlighted in Figure 2, Figure 3 and Figure 4 (all below) are being relined under the AMP7 [REDACTED] [REDACTED] scheme.

Figure 2: Open Culvert under [REDACTED]



Source: Thames Water

- 3.6. The same mains shown in Figure 2 above, also run under the foundations of a property further along the route as shown in Figure 3 below. Again, any catastrophic failure in this location would potentially cause significant structural damage to the property near instantaneously.



Source: Thames Water

- 3.7. A further example of the dangers of flood risk to basements can be seen from the 2021 flash flooding event in New York, which demonstrates the extreme scenario of the flooding risk that subterranean properties can be exposed to in cities.⁴ In this instance, pluvial (surface water) flooding resulted in the tragic deaths of eleven people who were trapped in their basement properties.
- 3.8. Figure 4: Example risk to a basement property shows how easily water from a trunk main burst can enter subterranean properties. This photo was taken from a burst event in October 2019 that flooded 100 properties, 45 of which needed to be rehoused. There is no barrier between the street level and entrances to subterranean levels.

⁴ <https://www.theguardian.com/us-news/2021/sep/04/new-york-floods-11-die-basement-apartments>

Figure 4: Example risk to a basement property



Source: Thames Water

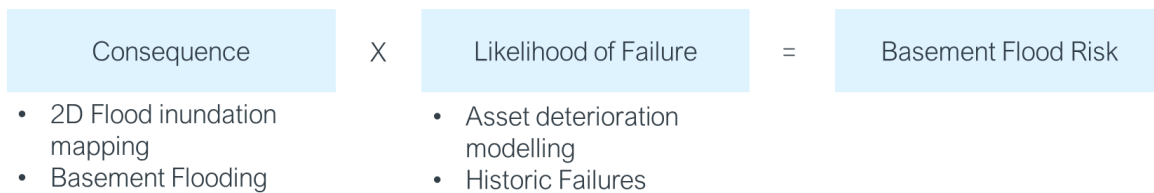
3.9. The proximity of basements to our assets and the resulting near-instantaneous consequence of trunk main failure are outside of our management control. [REDACTED]

[REDACTED] Therefore, given that we would be unable to respond quickly enough to a catastrophic failure event of our trunk main network to prevent basement flooding (it typically takes forty minutes to an hour on average for our operatives to attend a failure in London), we must proactively rehabilitate sections of trunk mains prior to experiencing failures to sufficiently mitigate this risk for customers.



3.10. We have applied a risk-based methodology to determine our prioritised list of schemes for AMP8, which uses flood inundation mapping and basement property data to estimate the consequence of asset failure along our trunk main network, we have then estimated the likelihood of future failures occurring using our database of historic failures and asset deterioration modelling.

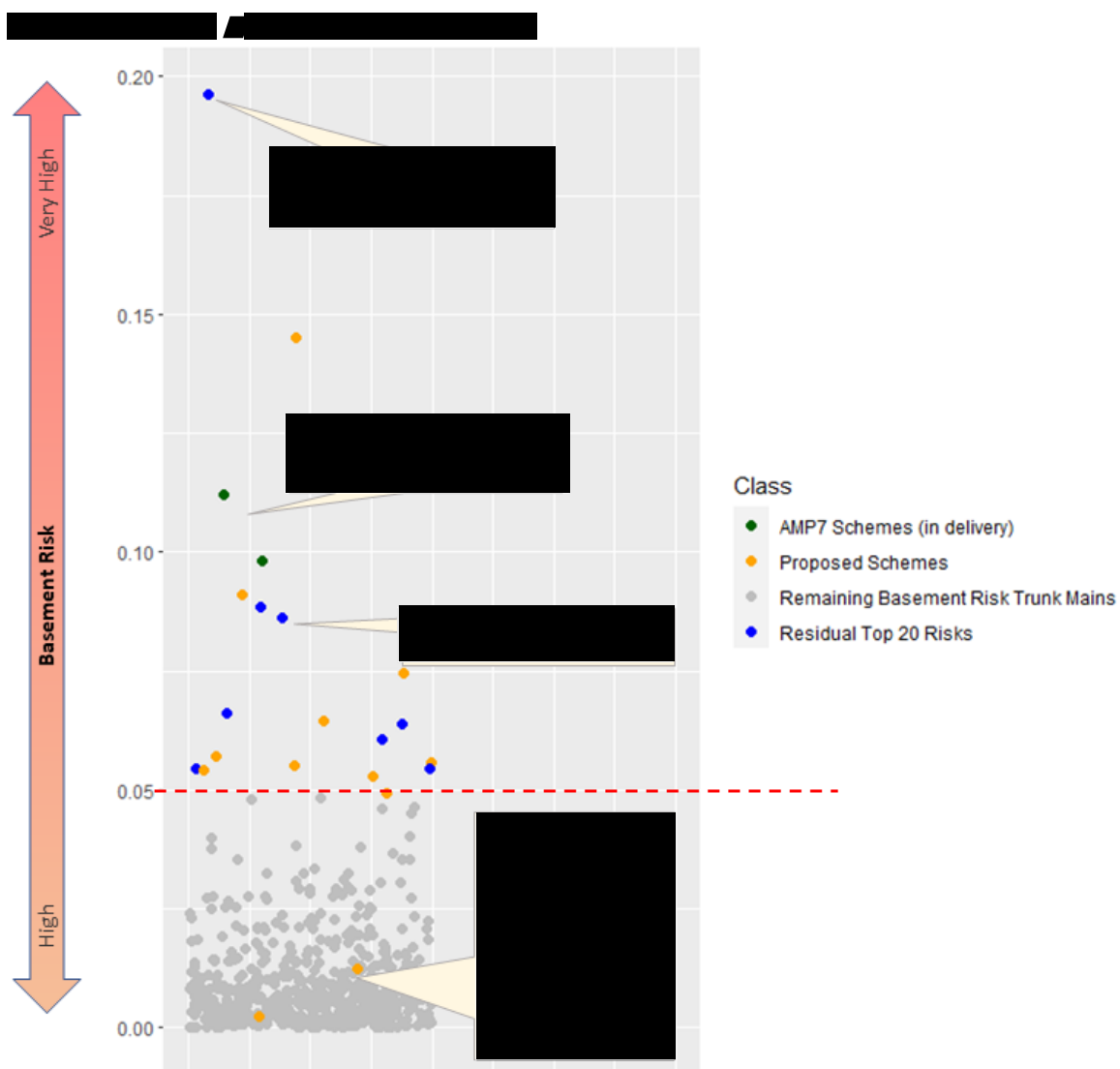
Figure 6: Basement Flooding Risk Methodology



Source: Thames Water

3.11. The outcome of this can be seen in Figure 7 below. Each dot represents one of our trunk mains. The Y-Axis denotes the basement risk associated with the trunk mains and is calculated using the number of basements per metre of main multiplied by the annual probability of failure. The X-Axis shows the relative distribution of the level of basement risk associated with our mains. To highlight the disproportionate basement risk posed by a very small proportion of our network we have also summarised the length of trunk main broken into different risk bandings in Table 5.

- 3.12. Figure 7: Thames Water basement flood risk, represents our modelled view of basement flood risk. As stated above, we have used our externally verified trunk main model as a guide only, and have supplemented our analysis with real-world, operational insight to define the list. For example, we have prioritised Herne Hill A and B schemes for inclusion within the AMP8 programme given that we experienced a recent failure here and believe the model to be under-estimating the consequence of failure. The fire brigade was called to assist with this burst and had to evacuate people from their homes.
- 3.13. We are also awaiting condition data on Hyde Park Corner before deciding upon its inclusion within the AMP8 programme, as we believe the model is overestimating the probability of failure occurring.



Source: Thames Water

Table 5: Thames Water Basement Flood Risk

| Basement Risk | Length (km) | Cohort |
|---------------|-------------|-------------------------------------|
| 0.15 - 2 | 0.9 | Residual Top 20 Risks |
| 1 – 0.15 | 1.0 | Proposed Schemes |
| | 0.7 | AMP7 Schemes (in delivery) |
| 0.05 - 1 | 11.4 | Proposed Schemes |
| | 0.8 | AMP7 Schemes (in delivery) |
| | 1.6 | Residual Top 20 Risks |
| 0 – 0.05 | 2.3 | Proposed Schemes |
| | 324.3 | Remaining Basement Risk Trunk Mains |

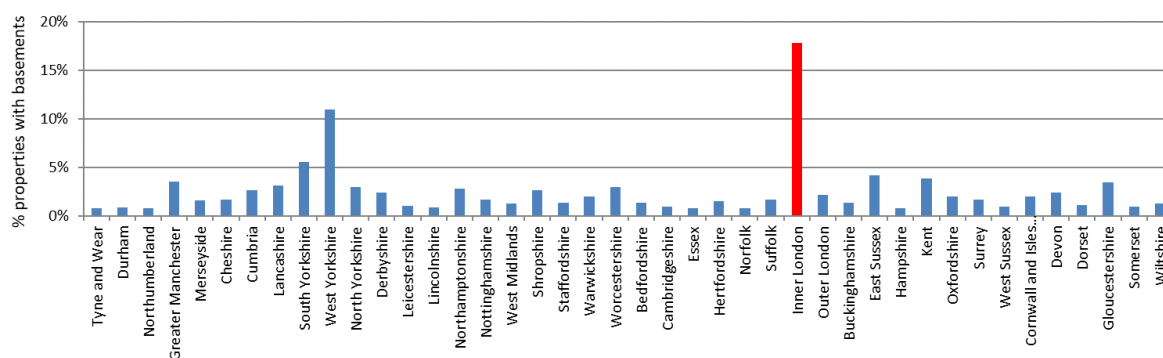
Source: Thames Water

- 3.14. Our risk assessment found 37,545 basement properties were at the highest risk of flooding. We will seek to address the risk at all these properties by 2050 but have prioritised those with the greatest number of affected basement properties and highest likelihood of failure to be addressed during AMP8. We plan to deliver 10 schemes across AMP8 but have included a long list of our top 20 prioritised schemes from which we will substitute schemes if we are unable to deliver any of the 10 schemes within the AMP period due to deliverability concerns such as road access.
- 3.15. We recognise the current cost of rehabilitation of some of our largest trunk main assets is high and there are limitations in current long-length condition assessment technology. We expect both these aspects to improve under our Best Value Pathway in future AMPs, where we will be able to deliver a greater volume of work, with higher confidence and greater efficiency. We consider our approach balances the long term need to protect all customers in a basement property with unacceptable risk by 2050.

The consequences of a trunk main failing in London are worse than other regions

- 3.16. In this section we demonstrate that customers in London face a higher risk of basement flooding compared to customers in other regions and why an enhancement programme to reduce this specific risk is necessary.
- 3.17. Inner London contains both a higher total number and a higher proportion of basement properties than any other area in England.⁵ Furthermore, the number of basement properties in London has been increasing due to a combination of high property prices, increasing population density and the wealth of residents – a 2017 survey found that 75% of the UK’s total applications for basement extensions were in London.⁶ In addition, more than 7,000 basement additions had been built in London during the 11-year span between 2008 and 2019.⁷

Figure 8: Percentage of properties with basements (defined as Lowest Floor Level - UV61)



Source: ONS, 2001 Census Data., ONS no longer collects data on floor levels within properties.

- 3.18. As highlighted in Yorkshire Water’s PR19 cost adjustment claim, they also have a high proportion of cellared properties.⁸ As can be seen in Figure 8 above which uses an updated data source, the basement density is far greater in inner London.
- 3.19. We have already experienced trunk main failures that have impacted basement properties in London; two such events during AMP6 are shown in Table 6 (Below):

Table 6 : Examples of Large Trunk Main Failures in AMP6 affecting basement properties

| | |
|--|---|
| October 2017 – Eversholt Street, Somers Town | A 16” main failed causing basement residents to need evacuating by the London Fire Brigade. We have replaced the highest risk section of the main in AMP7. [REDACTED] |
|--|---|

⁵ ONS [2001 Census Data](#). ONS no longer collects data on floor levels within properties.

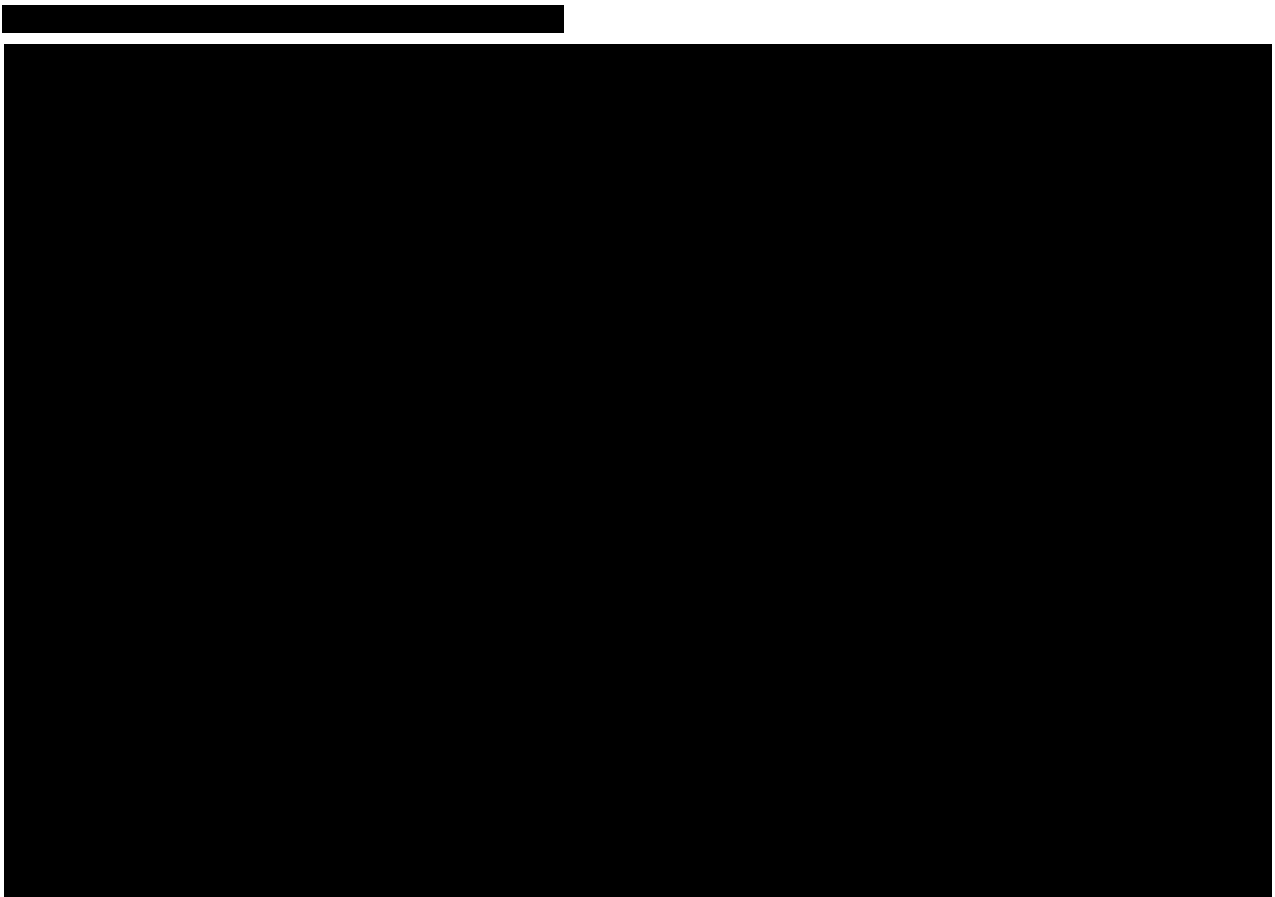
⁶ <https://www.foxtons.co.uk/discover/2017/02/75-of-all-uk-basement-conversions-are-in-london.html>

⁷ <https://www.ncl.ac.uk/api/news/item/bunkering-down/>

⁸ [appendix-8k.pdf \(yorkshirewater.com\)](#)

| | |
|--|---|
| | [REDACTED] |
| <p>October 2019 – near 147 Queens Drive, Finsbury Park</p> | <p>A 36” cast iron main built in 1894 flooded 100 properties, 45 of which had to be rehoused. There had been no previous recorded major bursts on this trunk main.</p> <p>Following our investigation as part of our rehabilitation response, we identified properties near the event were within 10m of three major trunk mains, the failure of any of which would result in the inundation of these basements near instantaneously – a risk that no emergency response could mitigate for these properties.</p> |

3.20. Our trunk mains typically follow roads, where the diameter and route reflect the needs of the customers and environment at the time of construction. Figure 9 [REDACTED]
[REDACTED]
[REDACTED] We undertake flood modelling to determine the likely extent of flooding using the SBPs, burst flow hydrographs, digital terrain model (DTM), roughness coefficients (i.e. resistance to flow) and drainage rates.



Source: Thames Water

3.21. The density of basement properties in London combined with the size and proximity of our trunk main assets causes a higher risk of basement flooding for our customers than in other regions.

The likelihood of a trunk main failure in London is higher than other regions

- 3.22. Not only does London have the greatest density of basement properties when compared with other regions of the UK, but the risk to customers is also heightened by our more complex and older network that is impacted by significant elements outside our management control.
- 3.23. There is no clear trigger that we can pre-empt to prevent catastrophic bursts based on findings from historical events. Following the eight high profile bursts in 2016 and 2017, the independent Trunk Mains Forensic Review found a range of failure modes across our network⁹. There was no discernible link in the times of day of the bursts, nor the causes of the bursts.
- 3.24. The review found the failures were due to:
- **Inappropriate pipe supports.** Rotted supports or pipes bearing directly on a brick structure placed stress on the pipe and when combined with repetitive, heavy traffic loading led to elevated the stress on the pipe at this point
 - **Significant corrosion.** All failures were cast iron mains. One case was considered to be exacerbated by stray electrical currents from the nearby railway line. A couple of highly corroded pipes finally burst due to transient pressure or localised vibrations
 - **Heavy vibrations.** Workers' equipment or recharging of mains created stress in the pipe.
 - **A combination of factors.** This event was driven by significant corrosion, stress concentrations from arrangement at time of installation, leakage, and traffic loading causing additional displacement and stress. It is thought a pressure wave caused the final fast fracture of the joint
- 3.25. The review also identified several contributing factors to the events:
- Some wartime repairs were likely completed in a hurry and were not fully executed to standard or documented. Hence the data held on the condition of each trunk main is not necessarily accurate for the whole main's length
 - The significance of a leak's location can mean an extended approval process, for example, to receive approval from TfL to shut part of a red route
 - Poor data quality meant assets were excavated or isolated incorrectly, or neighbouring works impacted the trunk mains
- 3.26. The variation in the causes and triggers for these events (the most complete review we have undertaken into a cluster of failures on our trunk main network) show the uncertainties and risks around these assets, where highly localised factors in an otherwise good asset can lead to a catastrophic failure. This work by two globally leading experts emphasised the importance of understanding our pipes' condition at a highly granular level – a key plank of our long-term strategy for these assets.

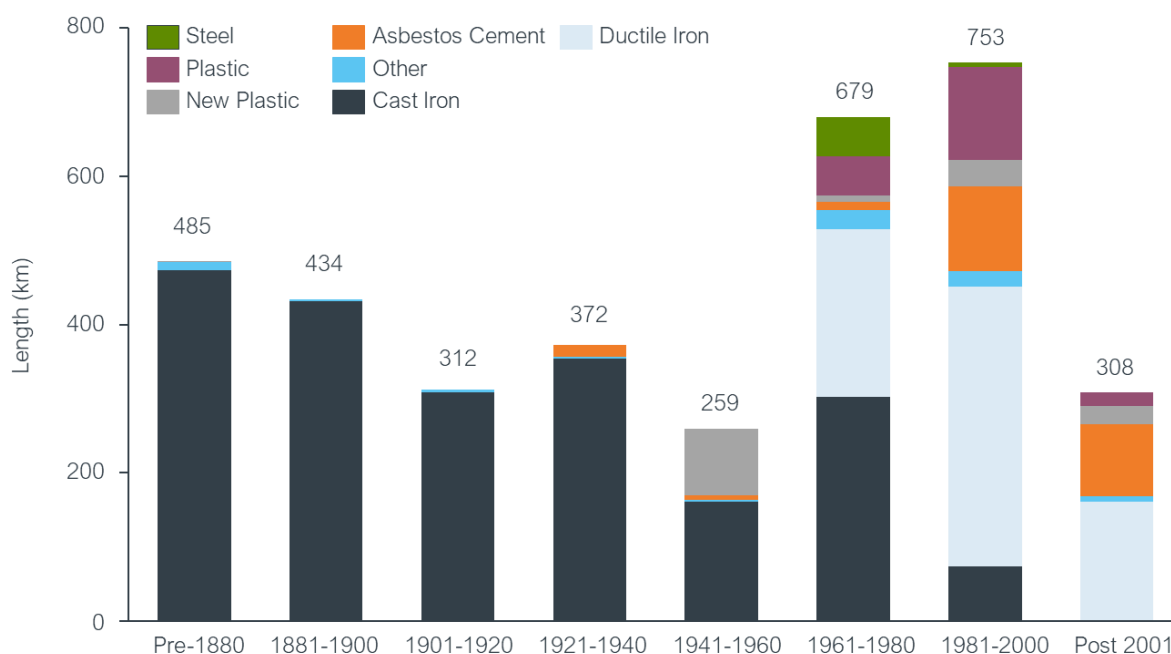
⁹ Paul Cuttill OBE, Thames Water Trunk Mains Forensic Review: Final Findings Report, 24 March 2017; which is [available on our website](#).

3.27. An independent report carried out in 2021 found Thames Water’s asset health in London is affected by several factors more than any of its peers, including:¹⁰

- High percentage of corrodible cast iron pipes
- High percentage of pipes greater than 100 years old
- High percentage of pipe with no corrosion protection
- High percentage of corrosive clay in soils
- High percentage of shrink/swellable clay
- High streetworks disturbs sites
- High traffic flows per km and vehicle loadings
- High road junctions, per km of road

3.28. We set out the current age and material of our trunk mains in Figure 10, where the overwhelming majority of mains are shown to be cast iron. The trunk main network comprises of cast iron (CI) (67%), ductile iron (DI)(16%) and smaller portions of steel (ST), glass reinforced plastic (GRP), polyvinyl chloride (PVC), concrete and asbestos cement (AC) pipes.

Figure 10: Trunk mains by age and material across Thames Water’s whole network



Source: Thames Water analysis of internal data and APR

3.29. Our trunk main network is the oldest in the UK, with an average age of mains of over 78 years old. In London, trunk mains average over 100 years old and 13% of the network is over 150 years old (the oldest pipe was laid circa 200 years ago). It is one of the largest in the UK (by length and diameter), with pipes ranging up to 60” (1,500mm) in diameter.

¹⁰ LWI.G2.E1 Rationale for London Additional Expenditure: Factors Affecting Performance and Costs, provided to Ofwat at gate 2 under our LWICA programme.

- 3.30. Before the rationalisation and nationalisation of what was to become Thames Water, London was supplied by numerous private water companies in the in the eighteenth and nineteenth centuries, each with a large proportion of pipes still in operation today. As a result, there is excessive redundancy in the network in places and our long term strategy is to identify these locations and rationalise the network where possible and we are developing digital tools to support the design of a right-sized network of the future.
- 3.31. Reactive, wartime repairs were undertaken under the time pressure of the Blitz bombing raids where the priority was to restore water supplies as quickly as possible to fight the fires of the East End. Material quality was also variable, due to the privations of war time, meaning that the quality of repairs was variable and with little documented evidence of this period, details of these works and the subsequent failure risk are not identified by cohort level modelling and remain unknown until Thames Water excavates the site.
- 3.32. We must prioritise rehabilitation for areas at high risk of basement flooding, because past high-profile events have occurred at locations where there was sometimes no history of bursts or leaks and a purely reactive replacement programme is not acceptable to us. We know the condition of a trunk main can vary across its length based on traffic loadings, pipe arrangements and surrounding conditions.
- 3.33. Therefore, Thames Water must take a more risk adverse approach to trunk mains failures in London due to the higher consequences of failure compared to other regions. Although the likelihood of asset failure is assessed using a number of metrics, of which age is only one, the need for proactive trunk main replacement is more pressing than for other water companies in the UK because our network is older, and therefore further along the deterioration curve than others.

Customers and stakeholders consider addressing basement flooding risk is a priority

- 3.34. We have conducted research into our Enhancement Cases to understand our customer, community and stakeholder views on the need for enhancement and as well as their preference of proposed solutions, where appropriate.
- 3.35. Our engagement approach has combined an ongoing, iterative triangulation of insights over the course of AMP7 as well as targeted research on specific Enhancement Cases for our PR24 plan. A full list of sources used is available in our What Customers, Communities and Stakeholders Want (WCCSW) document¹¹, which is our single unifying customer insight framework, underpinned by detailed insight.
- 3.36. Our case for reducing the risk of basement flooding has been developed through discussion with over 1,600 current household customers, over 500 current non-household customers and over 60 future customers. The engagement has been through a mix of in-person workshops, online surveys and community discussions including:

¹¹ TMS04 What Customers, Communities and Stakeholders Want

PR24 Enhancement Case deep dives in February 2022¹²¹³, PR24 Enhancement Options Package Research in September 2022¹⁴, PR24 engagement case deep dives in May 2023 and PR24 Plan/bill acceptability in May 2023. A summary of the engagement and key insights at each stage of our research is presented in the table below.

- 3.37. Generally, customers value investment in trunk main rehabilitation schemes very highly, given the potential catastrophic consequences of failure. Customers strongly support a change of approach to regular and proactive renewal (74% favoured a high increase in activity), starting with pipes most at risk (PR24-10) and favour a 'prevention rather than cure' approach. Our London customers were particularly enthusiastic about this enhancement, reflecting level of risk in London compared to other towns and cities in the UK (PR24-12).
- 3.38. Throughout the engagement with customers, it was clear that once customers appreciated that the case is a safety issue, with potentially life-threatening consequences, rather than an asset maintenance or service level issue, the valuations became much higher.

¹² PR24-10 PR24 Deep Dives: Trunk Mains and Replumb London. February 2022

¹³ PR24-13 PR24 Enhancement Case Deep Dive Summary

¹⁴ PR24-12 PR24 Options Research. September 2022

Table 7: Thames Water Customer Research Summary

| Date | Research | Sample + method | Questions | Key insights supporting the need for enhancement |
|--------|---|--|--|---|
| Feb 22 | (PR24-10/13) Enhancement Case deep dives: trunk mains & 're-plumb London' | <p>Qualitative community (text based individual discussions)</p> <p>35 household customers</p> <p>5 future customers</p> <p>5 non-household customers</p> <p>These were all dual water/waste customers, broadly representative of customer base, across the region.</p> | <p>Support for trunk main and distribution mains replacement (no costs discussed)</p> <p>Final question to rank vs 6 other water and waste enhancements: net zero, lead pipes, sewer capacity, sewer overflows, bathing waters, chalk stream abstraction</p> | <p>Customers are concerned about the condition of distribution pipes and the potentially catastrophic impact of a trunk main bursts. When compared to other Enhancement Case areas tested, customers see replacing trunk mains as the top priority, closely followed by the replacement of distribution mains.</p> <p>A core component of our corporate strategy is that the health and safety our community and our employees should be protected through all reasonable measures. Our engagement with customers and stakeholders shows that they strongly support this position.</p> <p>Our customers expect us to maintain our network of water pipes and treatment works to ensure it is fit for purpose, providing safe and clean water on demand. They also expect us to replace and renew ageing infrastructure, investing in long-term and cost-effective solutions and technology to maintain a reliable service.</p> <p>Our customers' unanimously support proactive replacement of both trunk mains and distribution pipe and are supportive of a movement towards a programme of regular, proactive renewal of our water network.</p> |

| | | | | |
|-----------|---|--|--|--|
| Sep 22 | PR24-12 Enhancement options packages | <p>Qualitative in-person workshops 42 household customers 11 non-household customers</p> <p>Quantitative online survey 640 household customers 320 non-household customers</p> <p>These were all dual water/waste customers, broadly representative of customer base, across the regions (qual in Reading and London).</p> | <p>Discussing elements of and then trading off different bill impact packages of 8 Enhancement Cases:</p> <p>Trunk main replacement to protect basements at risk of flooding, lead pipes, water supply reliability, improving water treatment, sewer flooding, sewer spills, river health, carbon emissions</p> | <p>Customers overall are favourable of this enhancement, however, the strength of this favourability is mixed depending on the customer location(i.e. London vs non-London) and whether the customer prioritises individual or societal benefits. For some, the impact feels narrow and unfair, with potentially limited benefit (i.e. those in London and with basements whom some presume are therefore more 'wealthy'). Others feel resolving this could have long-term societal benefits in terms of reducing wastage and future-proofing Thames Water's systems</p> |
| May 23 | PR24-15 Enhancement Case deep dives: water (SEMD, basement flooding & major water supply interruption) | <p>Qualitative community (text based individual discussions) 53 household customers 8 future customers 19 non-households</p> <p>These were all dual water/waste customers, broadly representative of</p> | <p>Support for trunk main replacement or slip lining (combined programme @ additional £1 a year)</p> <p>Qual: Final question to rank vs 2 other water enhancements (SEMD and major supply interruption)</p> <p>Quant: Final question to rank vs 7 other water and waste enhancements (the above plus sewer flooding, sewer</p> | <p>Most customers are generally not concerned about basement flooding, however, they are surprised about the current risk and believe Thames Water have an ethical obligation to protect customers who may be impacted.</p> <p>Most customers want to avert basement flooding due to a perception that the disruption caused by repairing trunk mains will only get worse if left unaddressed.</p> |

| | | | | |
|--|--|---|--|---|
| | | <p>customer base, across the region.</p> <p>Quantitative online survey (telephone survey for digitally excluded)</p> <p>687 household customers</p> <p>51 future customers</p> <p>148 non-household customers</p> <p>61 digitally excluded customers</p> <p>These were all dual water/waste customers, broadly representative of customer base, across the region.</p> | <p>infiltration, sewage treatment works growth, bathing waters, rethinking rivers)</p> | <p>HH and NHH customers see this issue as more important to address compared with future customers.</p> |
|--|--|---|--|---|

Source: (PR24-10/13) Enhancement Case deep dives: trunk mains & 're-plumb London', PR24-12 Enhancement options packages, PR24-15 Enhancement Case deep dives: water (SEMD, basement flooding & major water supply interruption)

Stakeholder views

- 3.39. Key stakeholders including the GLA, customer groups and local MPs support a move towards more proactive investment in these assets. Following several catastrophic failures in 2016/17, Thames Water attended many local meetings with key stakeholders and customers¹⁵, including representatives of the GLA and the councils impacted. Serious concern was expressed in these meetings that London's residents and their property were exposed to unacceptable levels of risk due to the condition of the capital's trunk main network.
- 3.40. We have since then attended several scrutiny meetings with London Boroughs in response to catastrophic trunk main failures that have caused significant flooding. Following a major burst on Queen's Drive in Hackney in October 2019, which caused flooding to over 100 properties, many of them basement flats, we attended a scrutiny meeting, a selection of quotes from this meeting is shown in the Figure below.

Figure 11: Queens Drive Scrutiny Meeting Stakeholder Quotes

"I don't want to have to chair another meeting and hear from residents who have had their lives turned upside down by the floods, because even if everyone gets the compensation they're due and your homes are fixed and all the rest of it, that can't replace all the stress that everyone's been through. "I think it's extremely lucky, when some people live in basement flats, that no-one was killed or seriously injured. If this had happened in the middle of the night when people were asleep, we might now be talking deaths and corporate manslaughter."

"When it comes to the health and wellbeing of people, that is the last thing they really care about. I think that is a concept that needs to be changed."

Source: Thames Water

- 3.41. Following bursts in 2019 in Camden, on Eversholt Street, and 2022 in Islington on Tollington Drive, we attended two further scrutiny meetings. Again, a selection of stakeholder quotes is detailed in the figure below.

¹⁵ <https://www.islingtontribune.co.uk/article/angel-flood-youre-disgusting-water-firm-is-told>

Figure 12: Camden and Islington Scrutiny Meeting - Stakeholder Views

"These concerns have been around for a very long time. This is Victorian, the kind of stuff you get on the Antiques Road Show. This is not a problem that is suddenly happening. Nothing has been done about this for years and years."

"If you see the impact on residents, you would be as exercised as I am. We need to make sure the best cure is prevention. Invest in your infrastructure."

Source: Thames Water

3.42. Figure 13 below shows an image of residents being rescued from their homes following the burst on Tollington Drive.

Figure 13: Residents being rescued on Tollington Drive following a trunk main burst



Source: Thames Water

- 3.43. More recently, we were asked to appear at Camden for a second time following a major burst on Belsize Road which left dozens of properties flooded. Much of the discussion was about investing in upgrading the network.¹⁶
- 3.44. Further evidence of the stakeholder support for accelerating the replacement of these assets was provided following the announcement in September 2021 of the £300m conditional allowance programme, specifically to address long term performance issues relating to London's water network, with the Mayor of London quoted as saying: 'This new investment in Thames Water's supply network in London is a welcome and overdue start to renewing the ageing system that all Londoners rely on.'¹⁷
- 3.45. Furthermore, the GLA set out in their March 2021 document 'The Spatial Development Strategy for Greater London' as follows: 'In order to minimise the use of mains water, water supplies and resources should be protected and conserved in a sustainable manner. Development Plans should promote improvements to water supply infrastructure to contribute to security of supply. This should be done in a timely, efficient and sustainable manner taking energy consumption into account. Infrastructure investment is constrained by the short-term nature of water companies' investment plans. In order to facilitate the delivery of development it is important that investment in water supply infrastructure is provided ahead of need. To minimise wastage, water supply infrastructure improvements should give consideration to the replacement of ageing trunk mains.'¹⁸

This enhancement does not overlap with base or previously funded projects

Base programme targets capital maintenance around bursts and leakage

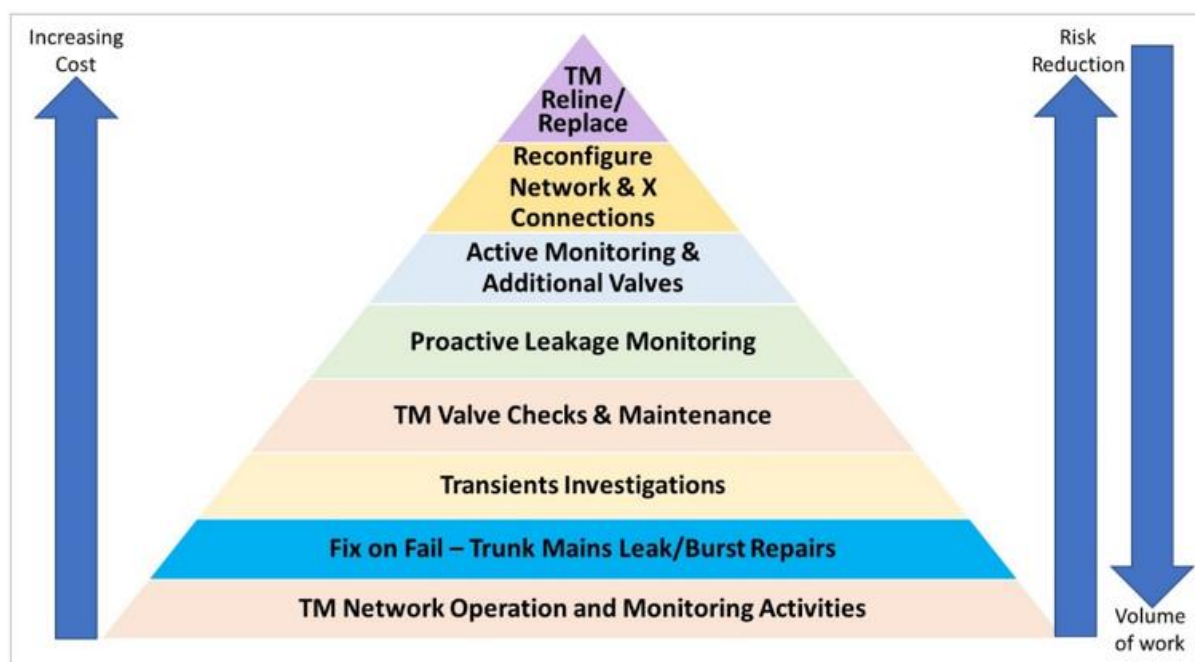
- 3.46. Through our base expenditure, we are undertaking various activities to deliver outcomes including reducing interruptions to supply, mains repairs and leakage. We will do this by prolonging the life of our trunk mains, improving network performance and mitigating customer service impacts from bursts (such as valve checks and maintenance, risk visualisation and rapid response). Our base plan will be prioritised taking a holistic view of risk.
- 3.47. Figure 14 illustrates the relative volume of work we undertake under our base trunk main management programme to maintain our network. Traditionally only short length, reactive rehabilitation schemes have been carried out under our base programme with planned trunk main replacement activity instead historically funded through significant shareholder contributions during AMP6 (£95m) and AMP7, which are over and above the Final Determination allowance.

¹⁶ A summary of the meeting can be found here: <https://www.camdennewjournal.co.uk/article/thames-water-says-money-has-to-be-found-somewhere-to-upgrade-main-pipes-after-belsize-road-floods>

¹⁷ <https://www.thameswater.co.uk/about-us/newsroom/latest-news/2021/sep/upgrade-of-londons-water-network-announced>

¹⁸ Greater London Authority, [The London Plan: The Spatial Development Strategy for Greater London](#), March 2021.

Figure 14: Trunk Base investment programme



Source: Thames Water

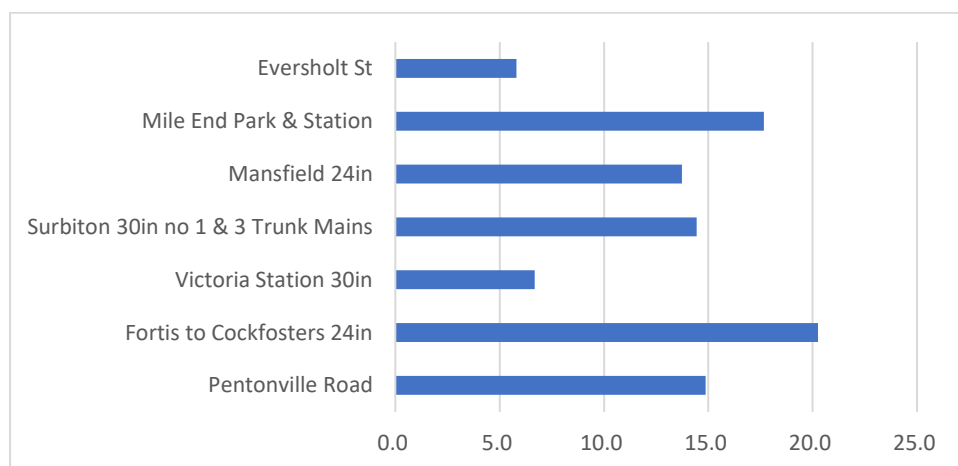
- 3.48. We are conducting an active trunk main leakage targeting, detection and repair programme with approximately 120 leaks repaired per year prioritised based on size and risk of failure. Moreover, we have increased the number of our trunk main in situ live monitoring units and extended our network coverage to 8% to improve the real-time insights on the performance of our network. We have also been carrying out over 2000 in-pipe leakage surveys annually for leakage detection and monitoring.
- 3.49. In response to the Trunk Main Forensic Review (2017)¹⁹, we undertook a strategic review of our trunk mains and made 15 commitments regarding our operating model, monitoring, asset information, risk management & event response²⁰
- 3.50. To meet these commitments, we have developed our ability to quickly identify and respond to bursts, implementing Rapid Response Areas for priority technician response to events and setting up a dedicated team in the Control Room to monitor our trunk mains. Furthermore, complete approximately 60,000 trunk main valves checks per AMP, prioritised by risk, which identify missing/unavailable valves which would limit our effectiveness to respond to a burst. A separate programme resolves these issues, again prioritised by risk.

¹⁹ Paul Cuttill OBE, Thames Water Trunk Mains Forensic Review: Final Findings Report, 24 March 2017; which is [available on our website](#).

²⁰ Thames Water, Thames Water Trunk Mains Strategic Review: Final Report, October 2017; which is [available on our website](#).

- 3.51. We are also in the middle of an ambitious programme of system calming in AMP7, where the operation of key assets such as pumps and valves are optimised to reduce damaging transient pressures entering our network, as we know extreme variations can lead to bursts especially in an older network.
- 3.52. Ultimately, our base funding for trunk mains must take a number of factors and drivers into account, such as reducing the risk of supply impact to our customers and improving our leakage and mains repairs performance. We use a risk-based approach to prioritise our sites for our base programmes. However, none of the initiatives described above are sufficient to mitigate the safety risk to the public and prevent basements from flooding.
- 3.53. Our base expenditure programme will not reduce the risk of basement flooding to customers quickly enough, particularly where there is no history of repeated reactive and proactive mains repairs. Without a new targeted programme of investigations and rehabilitation, we will not be able to mitigate the high risks of basement flooding and prevent catastrophic impacts for customers.
- 3.54. We are committed to completing the schemes we began under the London Water Infrastructure Conditional Allowance (LWICA) during AMP7.
- 3.55. Our LWICA programme enables the rehabilitation of some trunk mains but mostly focuses on distribution mains based on the modelled risk of bursts. By the end of AMP7, we will have addressed the risk in the very highest holistic risk category of trunk mains (25.8km), moving these pipes to lower risk bandings. A by-product of the LWICA programme is that we will have protected almost 2000 basement properties.

Figure 15: Summary of trunk mains projects and costs (£m) within LWICA



Source: Thames Water

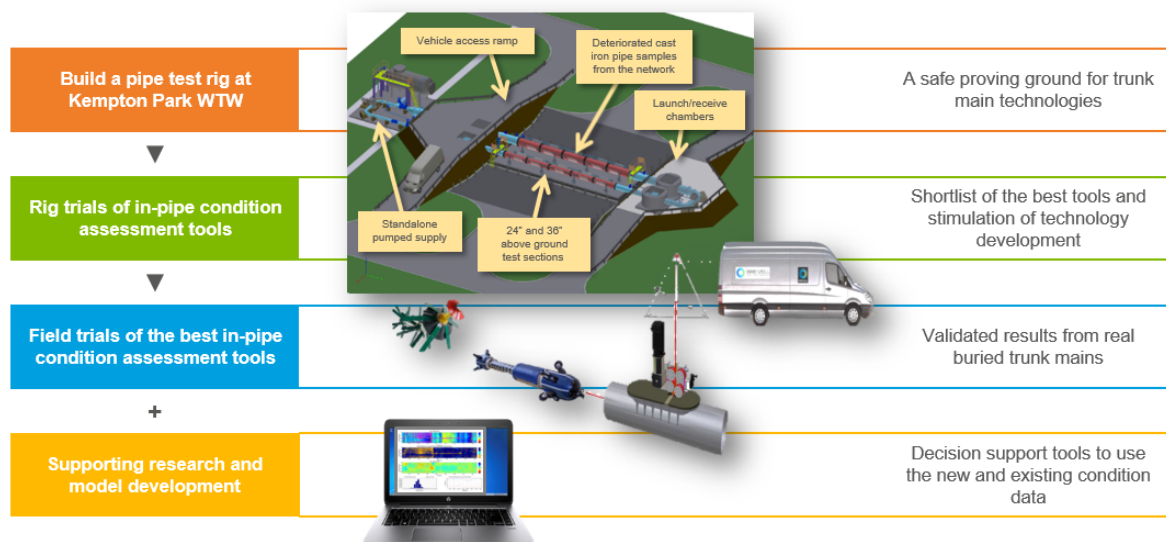
We start protecting the highest risk basement properties in AMP8

- 3.56. We intend to protect all basements at unacceptable risk levels by 2050, starting with the highest risk sites in AMP8. We found 37,545 basement properties are at very high or high

risk of basement flooding from 343km of trunk mains, based on failure likelihood and consequence for customers.

- 3.57. We will prioritise our 25-year investment based on the risk to customers through to 2050, where we will need to continually increase the length of trunk main rehabilitated AMP-on-AMP to cover the 343km. We will supplement the current risk assessment of flooding for basement properties with regular assessment updates and condition assessments, along with other network data, to re-evaluate our AMP-on-AMP delivery plan. Not all trunk mains will need to be replaced in the short to medium term.
- 3.58. Future improvements we expect in long-length condition assessment technology will enable us to determine which sections of main have a substantial remaining asset life. There is currently no viable long-length condition assessment technology available to the Water Industry, and current solutions only provide spot values for short (1m) lengths of main.
- 3.59. To further this advancement in long-length condition assessment technology we have recently constructed the Jeff Farrow Trunk Main Test Rig at Kempton Park WTW, allowing us to test pipes in different conditions, without risk to our essential services.²¹ We will be able to trial and develop in-pipe condition assessment tools on above ground sections of trunk main ranging from 24” to 36”. Our plan for the medium term is set out in Figure 16.

Figure 16: Approach to develop best practice condition assessment tools



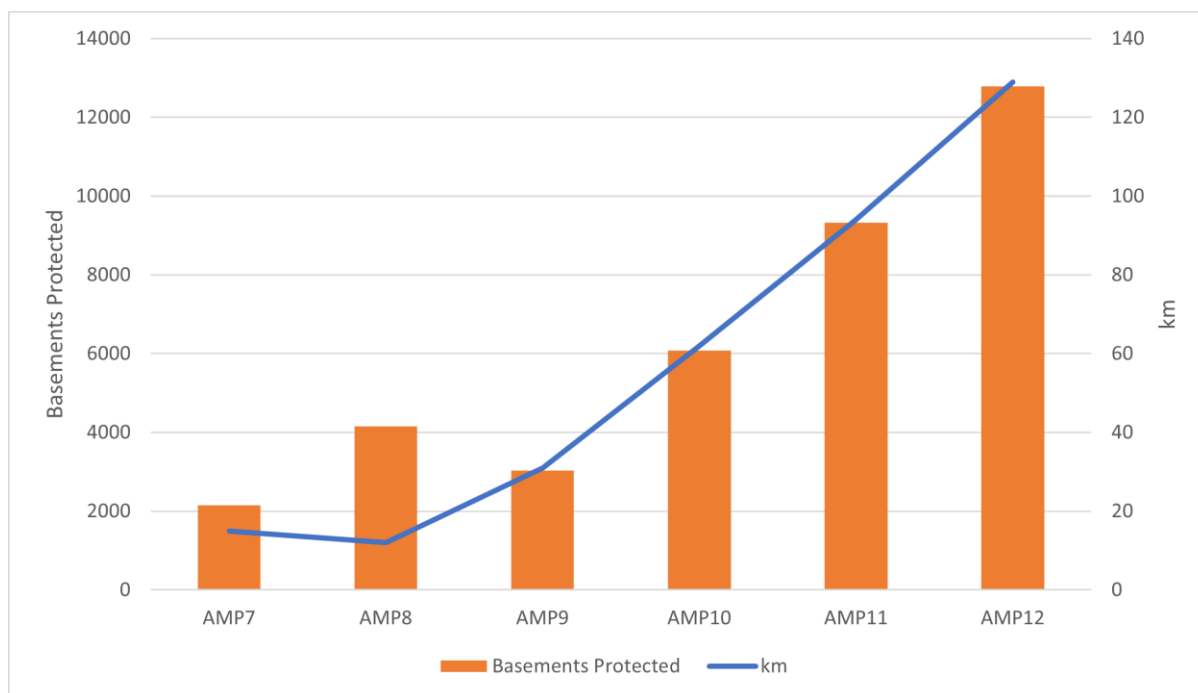
Source: Thames Water

- 3.60. Figure 17 shows our proposed annual delivery profile to protect a cumulative total of 37,545 properties by 2050. In AMP7 we will protect circa 2,000 properties as a result of

²¹ [£1.2 million trunk main test facility | Newsroom | Thames Water](#)

the works under our LWICA programme. Lessons learnt from previous AMPs improve our confidence in our preferred solution.

Figure 17: Annual targets for rehabilitation trunk mains and protect basement properties



Source: Thames Water

(Note – drop in the number of basements protected in AMP9 is due to targeting of highest risk properties in AMP8 resulting in best return per km. AMP 9 will see a smaller number of basements per km as risk concentration reduces. The number will increase again as mains replacement km grows in future AMPs)

- 3.61. Since the high-profile basement flooding events in 2016, we have improved our modelling capabilities and asset information to better identify assets that are of greatest risk to public health and safety.
- 3.62. Critically, our move to a more advanced flood modelling to give highly granular flood mapping for points at least every 100m across our network, has enabled us to better identify all locations at risk of flooding following a failure. Subsequent improvements and validation mean we can produce a more realistic prediction of flood extents, such as the generation of flood extent and depth estimates for a burst at any point on our trunk main network.
- 3.63. Our improved probability model means we can now incorporate engineering deterioration curves for all major material types and differentiate between the chances of a leak and a burst at pipe level. We then quantify the extent of any impact of any flooding through our consequence model.
- 3.64. With our enhanced modelling capabilities, we have a clearer picture of the health and safety risk associated with our assets than in previous AMPs, waiting for a catastrophic

failure to occur before we decide to rehabilitate a section of main is not the strategy we wish to pursue. New intelligence and understanding of risk together with increasing customer expectations necessitates the need for proactive asset replacement of these high-risk sections of trunk main to deliver an enhanced outcome to our customers and is not considered standard maintenance of existing infrastructure.

- 3.65. Robust long-term investment is required for Thames Water to achieve its core pathway solution to reducing basement flooding (see Section 7). This core pathway assumes that: Technological improvements will be made is asset condition assessments, improved rehab techniques (no-dig, pinpoint reconditioning) all reducing unit cost and making distance rehabbed more efficient.
- 3.66. Based on the above; linked with an established continual rehab programme, Thames Water will look to remove the current cycle of (de) mobilisation costs and inefficiencies getting programmes established. It is hoped that linked with more effective condition assessments, that mains rehabilitation will become a constant BAU activity at a greatly reduced per KM price.

3. Best option for customers

- 4.1. We propose to rehabilitate 12km across 10 sites to mitigate customers at the highest risk of basement flooding. For AMP8, we have identified and developed solutions to protect over 4,000 of our highest risk basements, which are in London. In our Long-Term Delivery Strategy and core pathway for this Enhancement Case, we consider this scope for AMP8 reflects an appropriate trade-off between immediate risk reduction and delivering more cost-effectively in the future through innovative new rehabilitation techniques.
- 4.2. We considered a range of plausible solutions as part of our solution workshopping for reducing the risk of basement flooding. We found many interventions should be retained as options once the high-risk sites for basement flooding were identified.

Table 8: Initial consideration of technology options

| Category | Option considered | Option retained or not? | Reasons |
|---------------------------|------------------------|-------------------------|---|
| Capital investment | Trunk Main Replacement | Yes | Tried and tested method that reduces risk by preventing events from occurring. |
| | Trunk Main Slip-line | Yes | |
| Operational interventions | Cross Connections | No | Reduces the customer supply impact of a failure after a burst. Connecting two separate mains via a valve allowing for one main to be isolated in the event of a failure and the water re-routed via the other main, thus reducing the amount of time customer supplies are interrupted. Whilst this provides a supply risk reduction it will not reduce the risk of basement flooding from a burst and so does not meet the needs case. |

| Category | Option considered | Option retained or not? | Reasons |
|--------------------|--|-------------------------|--|
| | drainage systems | | with flood water from these large diameter trunk mains. Not practical or affordable to roll-out across inner London. For example, many of our 36" trunk mains regularly operate at flows in excess of 200l/s. Although some of our largest sewers could potentially cope with this flow during dry weather, the drains which feed our combined sewer network would throttle the flow greatly, meaning there would still be widescale flooding. Enlarging our drainage capacity to capture flood water is cost prohibitive. Moreover, this approach would contradict our corporate strategy to reduce input into the wastewater network. |
| | Flood protection barriers at high-risk locations | No | Require installation on-streets or customer properties, but previous feedback around intrusiveness to the local environment, community acceptability and responsibility over ongoing ownership. Even with regular maintenance of the assets, not sufficient to reduce the risk for all basements at high-risk trunk main locations. In inner London, barriers can disrupt property access, reduce available pavement and have regular intersections with roads parking access. |
| Behavioural change | Property type | No | Not plausible to incentivise people not to live in or use basements. |

Source: Thames Water

- 4.3. As detailed in the table above, in the event of a catastrophic burst in one of these high-risk locations, operational and response interventions measures will not be sufficient to mitigate the risk of basement flooding and associated H&S risk. The speed in which basements properties will be impacted by flooding makes operational and response interventions insufficient. We set out a case study on response interventions in Annex B.
- 4.4. Moreover, as per the table above, no alternative measures (nature-based solutions, behavioural change etc.) have been deemed realistic, practical and/or sufficient to reduce the risk factor to a suitable level for these high-risk trunk main locations. Transient investigation (calm networks) may have the potential to reduce the likelihood of failure, however the full long-term benefit of this approach is yet unknown and as such we have deemed this not to be viable in the short term. In the immediate future, asset rehabilitation is the only solution to effectively reduce the risk of basement flooding.

Options assessment for site solutions

- 4.5. For operational interventions, we identified that the calm network approach can be an option to reduce the risk for customers. We have been trialling this method as part of our AMP7 network operation and have three years of data to show its benefits. For us to adopt this method to reduce the basement flooding risk specifically for an identified site, we need to be able to carry out a long-length condition assessment to understand whether the pipe is structurally sound. The technology to undertake long-length condition assessments is not yet sufficiently developed to enable us to have confidence in this solution and we have therefore deemed it to be non-viable in the short-term. As we set out in Section 3, we are investing in research into better methods for condition assessments to enable us to undertake these more easily and at lower cost.
- 4.6. We have used our risk model approach to identify sites at risk of basement flooding, but we will conduct spot condition assessments as we approach the time to rehabilitate a site, consistent with our company process. Then we will have the latest information on any given pipe length before we finalise the project specification.
- 4.7. Until we have confidence in the entire length of at-risk sections, a capital investment solution is the only method proven to reduce the risk for customers.
- 4.8. Trunk main replacement and slip-line (pipe insertion) have been identified as the two feasible solutions to address the risk of basement flooding and reduce the risk to an acceptable level.
- 4.9. Unlike standard mains replacement, slip-lining is completed by installing a smaller, carrier pipe into the existing larger host pipe. The new pipe is pulled through the existing host pipe starting at an insertion pit and continuing to a receiving pit. The method can be carried out along a long length of trunk main, requiring a series of launch /reception pits at regular intervals (e.g. 150 meters).
- 4.10. Lining existing pipes reduces their internal diameter and therefore their effective carrying capacity, therefore this technique is not appropriate in all locations either because the current or forecasted demands of that pipe would not be met. In such instances, a more intrusive, traditional approach is required. This would typically involve decommissioning the existing trunk main and replacing it by laying a new pipe, known as the 'open cut' method whereby an entire trench needs to be dug along the route to lay the new main.
- 4.11. Accordingly for each site, we will develop options for trunk mains rehabilitation, but we will only finalise the solution for implementation once we have condition assessment data and have undertaken hydraulic modelling of the network. We will adopt a least cost approach to ensure we reduce the identified risk, but using the cheapest solution that delivers that risk benefit and meets the needs of the future.

Customer and stakeholder engagement

- 4.12. Different investment options relating to reducing the risk of basement flooding from trunk mains have been tested with customers as part of our latest Enhancement Case research.

Insights: Reducing the risk of basement flooding from trunk mains

Support for the solutions

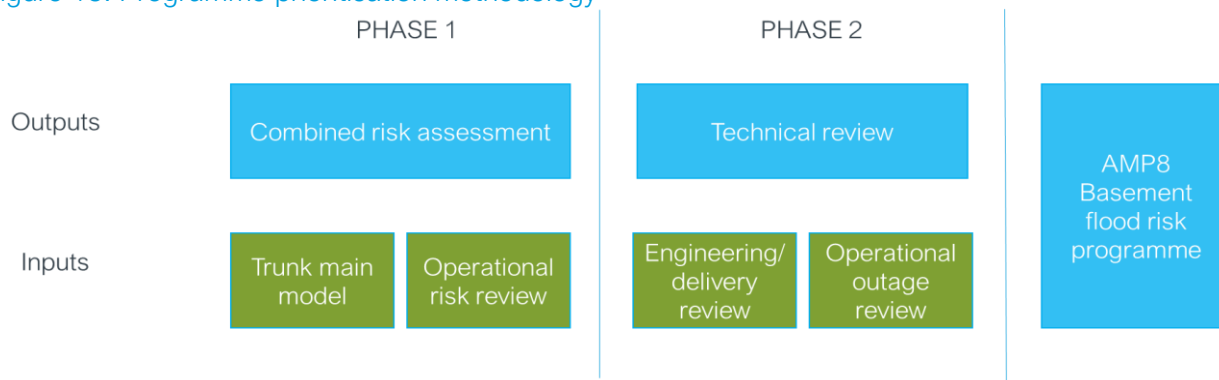
- **The vast majority of customers support Thames Water's plan** to reduce the risk of basement flooding as this will proactively and directly address the issue and minimise disruption in the long-term. However, customers want to know how more about costs and how much disruption will occur in the medium and long-term. (PR24-15)
- For this reason primarily, **'Reduce the risk of flooding by replacing trunk mains'** was the preferred investment of all customer groups. Future bill payers in particular favoured this approach as they recognised they would otherwise inherit this issue. (PR24-15)
- Customers reacted positively to the proactive replacement of pipes, however, the perception of this enhancement from customers more generally was that this issue was 'London-focussed' and only likely to benefit customers who they perceived to be wealthier (i.e. living in London in a property with a basement) than them. Therefore, despite the relatively low impact on their bills, many felt the money could be better spent elsewhere. (PR24-14)
- In the PR24 deep dive on the Trunk Mains Enhancement Case (PR24-10), customers told us they favour a 'prevention rather than cure' approach, however they expect better monitoring to keep costs and disruption to a minimum throughout any programme of work.
- Customers strongly support a change of approach to regular and proactive renewal (74% favoured a high increase in activity*), starting with pipes most at risk. (PR24-10)
- They are broadly split on whether to prioritise trunk mains, distribution pipes or both equally: customers favour prioritising trunk mains because this avoids catastrophic impacts, such as destruction of properties, and may have greater impact on leakage overall. However, prioritising distribution pipes feels like it will deliver a greater overall impact for customers as well as being cheaper and easier. (PR24-10)

**n.b. 1) the percentages shown on this page are based on a relatively small qualitative sample size, they are shown to indicate direction of sentiment only; and 2) there is slight bias in the way the proposed options were presented to customers in PR24-10 in that the proposal to change the approach of mains replacement and distribution pipe replacement listed more positives than negatives.*

Selection of high-risk sites and solution development

- 4.13. We developed our prioritised list of sites for AMP8 in two phases illustrated in Figure 18 below.
- 4.14. We began by combining our modelled view of basement flood risk and asset deterioration with a review of operational risks, to stress test our model results and narrow the list of sites for possible investment in AMP8.
- 4.15. We then undertook a technical review of the high-risk schemes to ensure that they were deliverable in AMP8.

Figure 18: Programme prioritisation methodology



Source: Thames Water

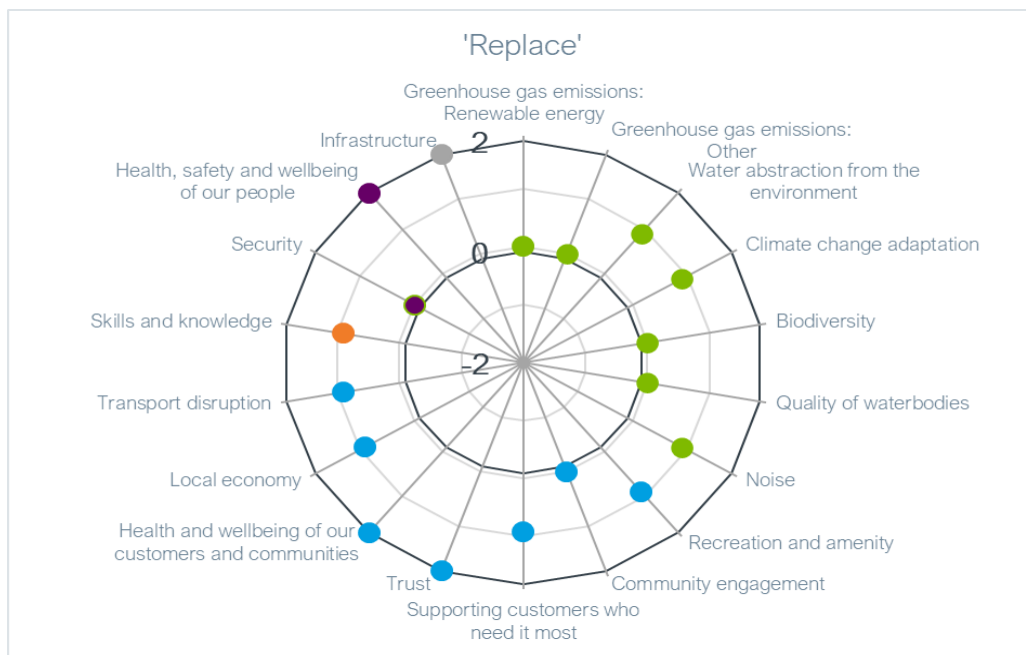
- 4.16. We conducted the option reviews between Engineering, System Planning and Operations, on a scheme-by-scheme basis centred on:
- Asset risk results – burst history, impact of failure, failure probability and modelled risk scores
 - Locational constraints – road and/or railway crossing on the pipeline route
 - Current state of play – valve availability, leakage detection options, monitoring locations, system operations incl. transient investigations and contingency planning
 - Options to mitigate (both operational measures & rehabilitation)
 - Potential scheduling – AMP8 and beyond
- 4.17. Hydraulic requirements were considered to indicate the type of solution across like-for-like replacement or slip-lining, upsizing or downsizing, depending on the impact of head loss, future operating strategy of the main and outage requirements.
- 4.18. The outcomes of the technical workshops informed our scope for mains rehabilitation. As explained in Section 5, we costed solutions using an average unit rate determined from a representative mix of trunk main diameters, site locations and rehabilitation techniques.
- 4.19. Our experience is trenchless technologies (slip-line) are often cheaper than open cut replacement in higher density urban areas such as London, where access, traffic control and the cost of reinstatement of surfaces become more expensive per meter of pipe, and where pipe depths are greater requiring expensive shoring and significant increases in excavation resources.²²
- 4.20. On a per length of trunk main basis, our cost estimates identify slip-lining as the least cost option on average. However, where a pipe's condition is found to be significantly corroded or other form of structural deterioration or deformity, slip-lining is not possible.
- 4.21. Another limitation is that the slip-lining method results in a reduced cross-sectional internal diameter once the project is complete and the main is back in supply. This is due

²² [Comparing the costs – trenchless versus traditional methods](#) [insert evidence into case]

to installing a smaller sized pipe within the existing host pipe, thus reducing flow rates and capacity. Hydraulic considerations must be taken into account on a case-by-case basis to ensure the rehabilitation solution is appropriate for both the current and future operating strategy of the section of main.

- 4.22. It is generally accepted that, during project delivery and construction phases, mains rehabilitation activities can cause disruption to local residents and businesses through full or partial road closures and the corresponding disruption to traffic and business activities, particularly in busy urban locations such as London.
- 4.23. The ‘trenchless’ slip-lining method typically causes less disruption to the local community during project delivery as only the insertion and receiving pits need to be dug, rather than an entire trench. Furthermore, customer research indicates that our customers expect us to keep disruption to a minimum throughout any programme of work²³ and there is clearly a negative association with any traffic disruption caused by our works. Additionally, this method typically results in fewer adverse environmental impacts such as damage to paved surfaces.
- 4.24. We have considered the public value generated by both open-cut and slip-lining rehabilitation methodologies as part of our optioneering. The outcome of our assessment is shown below.

Figure 19: Public Value Assessment - Open Cut

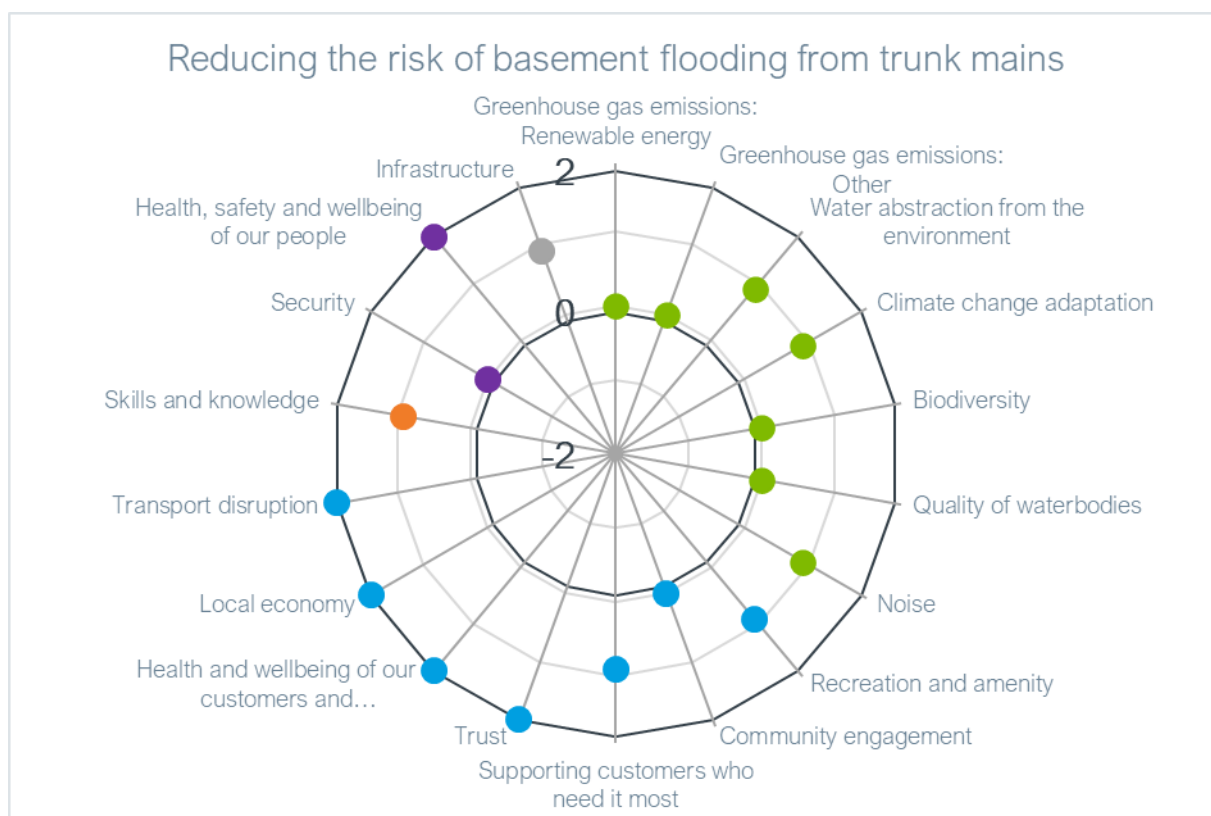


Total weighted score (out of 30): 13.4

Source: Thames Water

²³ Thames Water, CR32 Being a good neighbour, BritainThinks, March 2017

Figure 20: Public Value Assessment – Slip-lining



Total weighted score (out of 30): 14

Source: Thames Water

- 4.25. Therefore, although we consider slip-lining will be the best value option for customers on a per km of mains basis given both the lower costs and the reduced impact on the environment, our customers, and local communities we expect the programme to incorporate a blend of sliplining and open cut replacement methods.
- 4.26. Under a least cost approach, our ultimate use of mains replacement or slip-lining approach will depend on the site condition assessment, along with other the other factors mentioned above. Our price control deliverable in Section 6 enables us to return funding to customers if we find we do not need to complete the expected works.
- 4.27. We selected our preferred sites using combination of modelled risk, operational judgement and engineering review. We propose to address the risk for 10 sites in AMP8 shown in Table 3: AMP8 proposed schemes (long list).

Delivering Public Value

- 4.28. Delivering public value is about maximising the positive impact we have on customers, communities and the environment, as we provide water and wastewater services. It is about us being a force for good in our communities and the environment.
- 4.29. For us, public value is made up of all the things we do to make life better – through our essential services and our wider impact. It's about finding ways to make the biggest positive difference to customers, colleagues, communities and the environment.
- 4.30. To deliver our purpose, we have committed to incorporating public value within our investment thinking. With this approach we can identify every opportunity to make the biggest positive difference to customers, colleagues, communities and the environment as we deliver our service.
- 4.31. We're starting to implement a new approach to guide and measure both the public value we create and the delivery of our purpose. The public value framework helps us identify, evaluate and deliver public value which balances cost and value to customers, community and the environment over the long-term.
- 4.32. Our public value framework uses the capitals approach, an international decision-making framework. The capitals are categories of value that can be impacted by our activities.
- 4.33. Our framework uses this approach to understand how our success is directly or indirectly underpinned by natural, social, human and intellectual capital, as well as the traditional consideration of manufactured and financial capital. The capitals, along with Thames Water's customer-facing language for them and what is considered under each capital is set out in Figure 21 below.

Figure 21: The Capitals

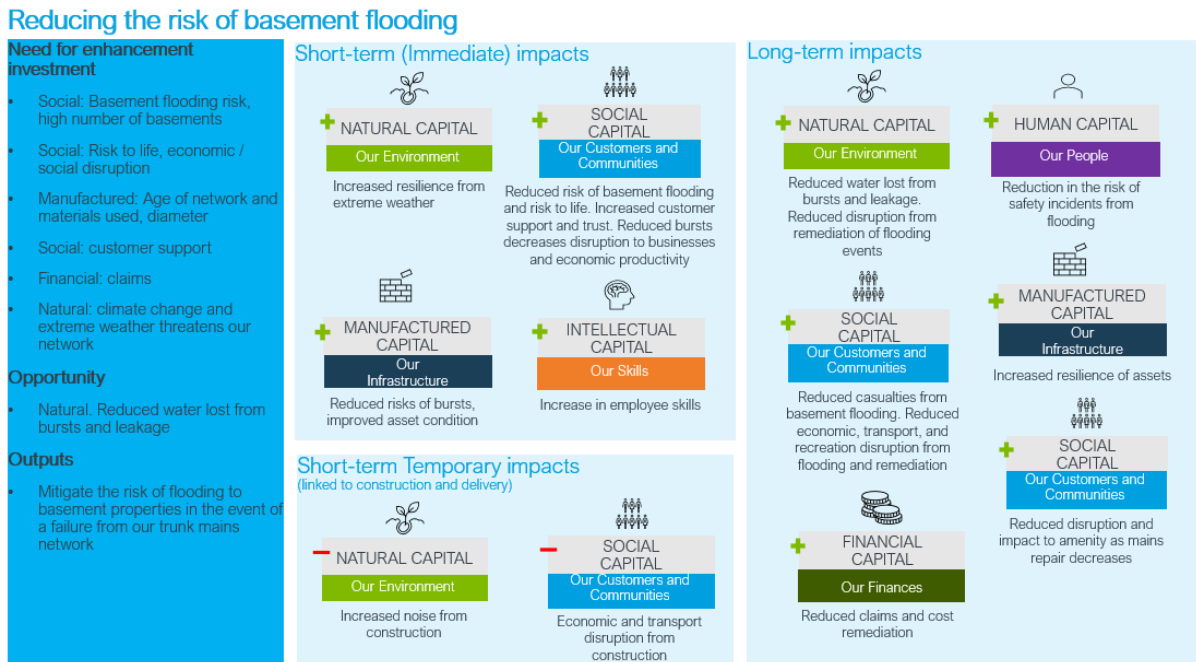


Source: Thames Water

- 4.34. We applied the public value framework here to fully understand how the investment leads to impact on the six capitals.

4.35. This investment grows value in social, natural, intellectual, human and manufactured capital. We discovered a range of short-term temporary, short-term immediate and long-term impacts. The theory of change infographic in Figure 22 shows how this investment leads to impact on the six capitals and delivers public value.

Figure 22 : The short-term temporary and immediate, and long-term impacts on the six capitals associated to the reducing the risk of basement flooding Enhancement Case.



Source: Thames Water

4.36. Our public value framework uses a semi-quantitative, multi-criteria analysis approach, where values are weighted using customer preferences²⁴. There are nineteen measures in our public value framework which are used to assess an option.

The public value framework assessment includes a wide range of measures such as biodiversity, waterbody quality, recreation, amenity and local economies, while the financial capital measure continues to be captured in other parts of our investment planning processes. The framework considers both short and long-term impacts, looking approximately 30 years ahead.

4.37. The degree of impact between the capitals varied. These are outlined in Figure 23 below.

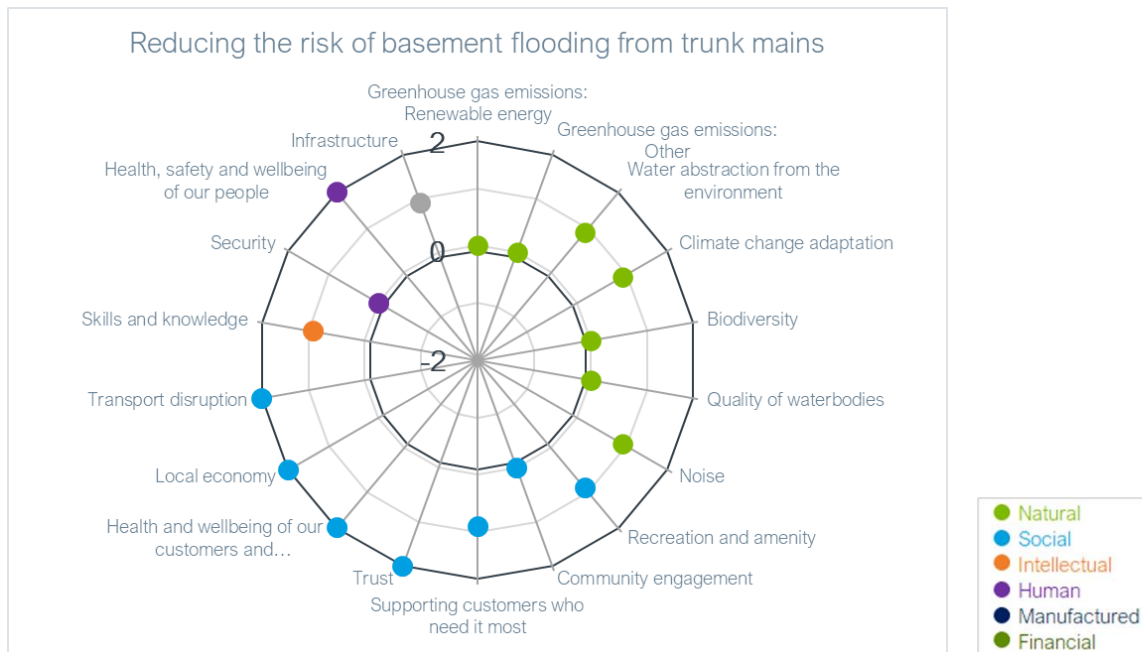
4.38. The investment strongly benefits social capital in one or more measures. This investment reduces the risk of basement flooding and risk to life for those customers at risk, including

²⁴ Public value research, May 2022 [Verve](#)

vulnerable customers, and therefore has a direct benefit to the health, safety and wellbeing of our customers over time.

- 4.39. As the risk of bursts, leakage and flooding decrease, less disruption caused by remediation will occur. Reduced economic, transport, and recreation disruption will improve community wellbeing and safeguard and safeguard local businesses' economic productivity.
- 4.40. We have overwhelming customer and stakeholder support to mitigate the risk of basement flooding. Delivery of this programme will reduce customer complaints in the long-term, generating trust and confidence between Thames Water, our customers and our stakeholders.
- 4.41. There is a strong benefit to manufactured capital as the rehabilitation improves our asset resilience, stabilises asset debt and increases the value of our assets.
- 4.42. There is a strong positive benefit to natural capital in one or more measures. Rehabilitation improves both condition and material to increase our resilience to extreme temperature variations driven by climate change. Our pipes will be more resilient to risks posed by extreme weather (freeze-thaw and/or long dry spells) which make catastrophic trunk main bursts resulting from poor asset condition or excessive joint movement less likely. However, this will have no direct effect on alleviating localised flooding from heavy rainfall.
- 4.43. Replacement of these assets will reduce the number of bursts and leakage. Visible leakage undermines our drought mitigation measures such as encouraging customers to use less water.
- 4.44. Delivery of the rehabilitation introduces a short-term dis-benefit with increased noise from construction and increased embodied carbon in project delivery. This is balanced by the benefit of reduced remediation visits, which will avoid increase operational carbon and noise pollution generated when repeating fix of the assets.
- 4.45. The investment strongly benefits people capital in one measure. As the risk of bursts, leakage and flooding decrease, this will reduce the requirement to access hazardous areas when responding to these events, consequentially reducing the risk of safety incidents.
- 4.46. This investment slightly benefits intellectual capital. The investment provides opportunities for our employees and supply chain to develop skills and experience, which would otherwise be less available without this investment.
- 4.47. An overview on financial capital is included in Section 2.

Figure 23: The results of the public value scoring for reducing the risk of basement flooding



Source: Thames Water

4.48. We will continue to seek public value opportunities through detailed design and delivery, for example through stakeholder engagement.

4. Cost efficiency

- 4.5. In this section, we cover the approach we have taken to arrive at our option cost and how we have considered the top-down efficiency of our proposed option.
- 4.6. Firstly, we set out the overall approach we have taken to developing our costs for this case. We describe the assumptions we have used to arrive at our proposed costs and demonstrate how we have challenged these bottom-up costs through the application of different operational efficiency levers.
- 4.7. We then set out how we have considered the cost efficiency of our proposed costs and whether benchmarking is appropriate. We describe our approach and how this has informed the considerations Ofwat should make when assessing the cost efficiency of our Enhancement Case.
- 4.8. Finally, we provide a recommendation for how Ofwat should assess the cost efficiency of our proposed enhancement.

How we have developed our costs for this case

- 4.9. In this section, we describe the approach we have followed to arrive at our costs for this Enhancement Case.
- 4.10. Several stages are required when developing engineering solutions for these large mains. Site visits and contractor involvement feature highly to fully understand the local conditions and identify the parties involved for permissions and issues.
- 4.11. The challenges around working in London's streets and communities mean that we will adopt a more flexible approach to replacements. For example, London experiences a higher traffic density than elsewhere in the country, lane rental costs and parking bay suspension costs are higher. No single technique is likely to offer the best value solution and therefore each project will be tested against a range of known workable techniques. These techniques include Open cut, Slip lining, Directional Drilling and Tunnelling.
- 4.12. Each main is to be assessed on a range of construction risks including nearby services, road closure/availability and outage duration etc. The projects are at an early stage of design maturity and therefore an analysis of risks along the mains is not available. The range of techniques available is to be matched to the risks present to give a more deliverable and lower risk solution.
- 4.13. The costing of these projects presents unique issues. There are no cost models that cover the sizes of these mains. We have carried out limited replacement of larger diameter mains in recent past and therefore have limited data points for comparison. Site specific factors such as compensation to local businesses, traffic management, and delivery timescales are typically a lot greater than for a distribution mains rehabilitation scheme and therefore the identification of the construction risks is extremely important.
- 4.14. Due to these challenges, we have taken an assumption-based approach to costing the schemes detailed in this case. The approach we have adopted uses an average unit rate for trunk mains replacement. The average unit rate is based on a representative mix of six schemes, comprising a mix of pipe diameters, site circumstances and a blend of solution types (slip lining and open cut).
- 4.15. Of the six schemes used to form the average unit rate, we have chosen two schemes that are in delivery. The further 4 schemes which we have used to form the average unit rate have been taken through a detailed costing exercise. More detail on our approach to costing can be found in TMS33 Capital Cost, Efficiency and Assurance.

How we have challenged our proposed costs

- 4.16. As outlined in TMS33 Capital Cost, Efficiency and Assurance, we have considered nine efficiency levers in defining our enhancement costs.
- 4.17. For this Enhancement Case, the application of each lever is summarised in the table below.

Table 9: Efficiency Lever Opportunities

| Efficiency Lever | Opportunity |
|-------------------------------------|---|
| 1. Asset Standards | Limited opportunity |
| 2. Programme Optimisation | Programme Optimisation is a strategic view of a programme of works, which identifies Efficiency through grouping and synergies, including process type, geography, site and scope |
| 3. Solution Optimisation | Investing in site data and establishing baseline performance will contribute to defining improved engineering solutions. This investment will enable Thames Water to effectively manage risks and make more informed decisions, thereby allowing for calculated risks to be taken to design and achieve the optimal solution. In this Enhancement Case, having reliable base data to support modelling, especially within the water treatment aspect, holds the potential to enhance the design process. This data will enable engineers to assess whether a no build/low build or smart build approach can be adopted, resulting in a more refined and optimized solution. |
| 4. Productisation / Standardisation | Limited opportunity |
| 5. Strategic Procurement | Based on the engineering scope for this Enhancement Case, it is anticipated that opportunities for strategic procurement will be limited due to the high repeatability and good pricing agreements established with Thames Water suppliers. Additional opportunities might arise by accelerating the dissemination of information to the market and providing suppliers and contractors with advanced insight into procurement requirements, particularly around the procurement of piping and there is an opportunity to realise through procurement with Operations. |
| 6. Innovation | Research into in situ pipe condition assessment and no-dig solutions continues, but benefits are not expected until AMP9 |
| 7. Digital & Data | The use of digital technology and solutions to improve project delivery, such as Building Information Modelling (BIM), Asset Information Modal (AIM), digital rehearsals using 4D, the use of augmented and virtual reality. The implementation of digital paperwork solutions, on-site tablets etc. This can be integrated with drones, laser scanning, LIDAR, digital data capture. Data analytics to optimise the solution. |

Source: Thames Water

Our proposed costs

4.18. In this section, we set out how we have arrived at our proposed costs for reducing the risk of basement flooding.

- 4.19. We have costed a list of 20 basement risks across our network, and these schemes are detailed in Table 3 - AMP8 proposed schemes (long list).
- 4.20. The list is separated into 10 schemes that we are proposing to deliver under this Enhancement Case during AMP8, the LWICA carry-over included within this Enhancement Case, and the remaining schemes are schemes that we will substitute in should there be deliverability constraints (such as road access) that would mean we would be unable to deliver a scheme within the AMP.
- 4.21. Costs for schemes have been estimated based on the average cost of six trunk main rehabilitation schemes, 2 of which are in delivery during AMP7 and 4 have undergone extensive cost assurance.
- 4.22. The schemes used in this costing exercise represented a range of pipe diameters, site circumstances and a blend of solution types (slip lining and open cut) and represent the typical mix of projects which we are likely to undertake to reduce the risk of basement flooding. We have then applied a programme level efficiency challenge.
- 4.23. Based on this approach, the total cost for the schemes, covering 12km of trunk mains replacement is £170m.

Our approach to determining cost efficiency

- 4.24. We have considered the most appropriate approach to assessing efficiency using the framework set out in TMS33 Capital Cost, Efficiency and Assurance. We reviewed the Enhancement Case against each of the criteria to determine whether we could undertake modelling, unit cost comparisons or demonstrate efficiency through our bottom-up engineering estimates. We discuss each of the relevant criteria in our framework below.

Comparability

- 4.25. Our programme of work in this area is likely to differ substantially from other companies, rendering direct comparison of costs ineffective. Our approach to mains replacement is fundamentally different to schemes being proposed by other companies, who do not face the same risks and constraints as Thames Water.
- 4.26. Our programme of trunk mains replacement will see us rehabilitating 12km of trunk mains across 10 sites, to mitigate the risks to customers at the highest risk of basement flooding. This programme is not comparable to trunk mains replacement programmes being proposed by other water companies, due to the complexity of work, the nature of working in London, density of other services and the diameter of our assets.
- 4.27. In addition, the age of our network means that cast iron mains make up most of the network and are shown to be susceptible to corrosion. We know the condition of a trunk main can vary across its length based on traffic loadings, pipe arrangements and surrounding conditions. Due to these factors, we must take a more risk adverse approach to trunk mains failures in London compared to other regions, due to the consequences and customers living in basement properties in close proximity to failures.

Availability of data

- 4.28. While other companies could potentially also propose trunk mains replacement enhancement schemes at PR24, the data available for comparison and modelling of costs across companies would not accurately reflect our costs in this area.

Cost drivers

- 4.29. Cost drivers in this area are complex, and our programme of work is subject to a wide range of compounding factors that are not shared by all companies. The complexity of cost drivers in this area will render accurate modelling of these costs across companies ineffective.
- 4.30. Large mains by their very nature have special construction issues relating to their size. They are always strategically important and therefore are problematic in taking offline with shutdown periods often being short. Normally located in dense urban areas with very limited space available for bypass arrangements the renewal techniques are normally limited to offline replacement which results in higher costs when compared to the replacement of distribution mains.
- 4.31. Within the next section we set out considerations Ofwat should make when considering the cost efficiency of our proposed costs using this approach.

Considerations Ofwat should make when determining our cost efficiency

- 4.32. In assessing the cost efficiency of our enhancement, Ofwat should consider the following features.

Thames Water-specific factors

- 4.33. The impact of trunk mains failing in London is higher than in other regions, as customers in London face a higher risk of basement flooding compared to customers in other regions. Inner London contains both a higher total number and a higher proportion of basement properties than any other area in England. Furthermore, the number of basement properties in London has been increasing due to a combination of high property prices, increasing population density and the wealth of residents – a 2017 survey found that 75% of the UK's total applications for basement extensions were in London. In addition, more than 7,000 basement additions had been built in London during the 11-year span between 2008 and 2019. We have already experienced trunk main failures that have impacted basement properties in London; two such events during AMP6.
- 4.34. In the highest risk properties, the speed with which basement properties would be impacted by flooding in the event of a catastrophic mains burst makes operational and response interventions insufficient, leading to high safety risks for residents of impacted properties.
- 4.35. A high percentage of pipes have no corrosion protection and/or the original coal-tar lining has been lost and many of these pipes sit in corrosive clay soils and have become heavily corroded. The report by Mott MacDonald provides substantial evidence on hazardous

soils. The report contains analysis to compare geohazards across the industry to show that London and Thames Water, as a whole, is affected by hazardous soil conditions more than other companies. The report also demonstrated a correlation between hazardous soils in our region and repair density, showing that aggressive soil conditions are an important factor in causing pipe failure and leakage and one which affects our region more than other parts of the country.

- 4.36. Our network in London is experiencing declining performance compared to other water companies due to certain characteristics which are outside management control, in particular:
- we are pumping more water relative to the size of our network;
 - our demand growth is out-pacing network growth; and
 - our soil types damage our network more than others.
 - The population and density of London requires a higher volume of water to be pumped through our mains network compared with other water companies.
- 4.37. As highlighted in the Mott Macdonald report, this requires higher pressures and friction across the network and one of the factors that results in increasing levels of leakage and mains repairs. Figure 6 below illustrates the volume of Distribution Input per length of main and shows that we are a clear outlier with a significant difference to the second water company and twice the level compared to the industry average.

Network asset age

- 4.38. Our network faces difficulties including the age of our network, the stress our network is under and the asset health of the network.
- 4.39. Our network has the oldest asset base of any water company, with 80% of our pipes dating to before the privatisation period. A high percentage of our pipes are over 100 years old. Circa 21% of our network is pre-1920, which is significantly more than other companies. Working on a higher proportion of much older assets raises costs and uncertainties.

Additional London constraints

- 4.40. Operating in Central London imposes constraints on our ability to replace trunk mains, raising costs. Conducting trunk mains replacement in central London frequently requires an extended approval process involving a range of stakeholders. As our trunk mains follow major roads, replacement of mains frequently requires close collaboration with TfL to manage the temporary closure of vital 'red routes' of public transport and other vital public transport hubs such as Victoria Station.
- 4.41. One of the sites identified on our long list of sites for intervention in this scheme Hyde Park. Conducting a mains rehabilitation programme in a royal park will involve extensive consultation and collaboration with Royal Parks, introducing costs for the delivery of this scheme that will not be faced by other water companies in the delivery of mains replacement programmes.

Data quality

- 4.42. Data held on trunk mains length may not accurately reflect our network. Due to the significant age of our network, we lack documentation on all historic repairs and works, particularly those conducted during the Blitz. Wartime work was additionally conducted at great haste and may not have been fully executed to standard.

Data granularity

- 4.43. Due to the size of our network, some of our trunk mains are significantly larger in diameter than the largest mains in operation across other companies. Ofwat's diameter categories lack granularity at higher diameters, and the category for the largest mains includes a very wide range of diameters. This underrepresents the size of the largest trunk mains in operation on our network, which are significantly larger than the largest mains of other companies. Directly comparing costs for the replacement of all mains in this category will dramatically underrepresent the costs of replacing the largest mains in our network, risking significant underfunding of critical works.

Network asset health

- 4.44. In addition to the factors discussed in detail above, an independent report carried out in 2021 found Thames Water's asset health in London is affected by several factors more than any of its peers, including:
- High percentage of corrodible cast iron pipes
 - High percentage of pipes greater than 100 years old
 - High percentage of pipe with no corrosion protection
 - High percentage of corrosive clay in soils
 - High percentage of shrink/swellable clay
 - High streetworks disturbs sites
 - High traffic flows per km and vehicle loadings
 - High road junctions, per km of road
- 4.45. The factors discussed in this section compound to render direct modelling of trunk mains programmes across water companies inappropriate as an approach to determining efficient costs for our risk-based trunk mains replacement programme.
- 4.46. The costs proposed within this case should be considered alongside the costs recently agreed with Ofwat for the London Water Improvement Conditional Allowance at Stage Gate 4. The LWICA programme contains schemes of similar complexity and variety to the schemes proposed within this case.
- 4.47. Recognising the limited ability of modelling to adequately consider and accommodate the factors discussed in this section, we recommend that Ofwat conducts a deep dive assessment of our costs in this Enhancement Case.

5. Customer protection

- 6.1. This Enhancement Case will enable us to rehabilitate 12 km of our highest risk trunk mains which will protect over 4,000 basement properties from potential flooding as the result of catastrophic bursts on the targeted lengths of main.
- 6.2. For this Enhancement Case we propose a price control deliverable of 'km of main rehabilitated'. We believe this to be a straightforward measure for our customers to understand and against which we can easily be held to account. This commitment aligns with the company's intention to proactively replace trunk mains that have been identified as holding a high level of risk, enabling us to mitigate the risk of flooding to our highest risk customers.
- 6.3. We have excluded length of trunk mains for the LWICA programme as these are covered by existing customer protection mechanisms.
- 6.4. We consider the high-level target ensures we deliver the same benefits to customers, but with the flexibility to adapt schemes and schedules where appropriate. For example:
- Each borough has different timeframes for reviewing and permitting works.
 - A condition assessment may reveal reduced or no works are required.

Table 10: Price Control Deliverable mechanism

| Scheme delivery expectations | |
|------------------------------|---|
| Description | <p>Rehabilitating 12km of trunk mains to reduce the flooding risk for basement properties by the end of AMP8. The company's risk-based assessment approach has identified a series of high-priority schemes required to reduce the risk of basement flooding for customers.</p> <p>Trunk mains rehabilitation includes the laying of new mains whose prime purpose is to replace an existing section of main, which is subsequently decommissioned.</p> <p>It also includes relining solutions such as pipe insertion/sliplining when used for this category of work and records any original main as abandoned. An adjustment to size classification should be made where rehabilitation activity results in upsizing or downsizing of mains.</p> <p>The company's forecast deliverables reflect a phased delivery programme that ramps up from mid-AMP8 to allow time for condition assessments and permitting.</p> |
| Measurement and reporting | <p>Length of trunk mains rehabilitation in number of kilometres, reported to one decimal place.</p> <p>For each scheme delivered, we will report the length of main rehabilitated annually parallel with the APR.</p> |
| Conditions on allowance | <p>Rehabilitation only includes the mitigations of reline and replacement solutions. Operational/response interventions such as proactive leak find and fix, monitoring, valve maintenance, cross connections are not included.</p> <p>Any trunk mains rehabilitated under the AMP7 LWICA are excluded.</p> |

| | |
|-----------|--|
| | Length of main rehabilitated must be attributable to the 343km of trunk main schemes identified to impact 37,545 basement properties. |
| Assurance | The company must commission an independent, third-party assurer to assure, to our satisfaction, that the above conditions have been met and the outputs of the scheme set out above have been delivered. |

Source: Thames Water

Table 11: Delivery Forecast

| Deliverable | Unit | Forecast deliverables (cumulative) | | | | |
|---------------------------------|------|------------------------------------|---------|---------|---------|---------|
| | | 2025/26 | 2026/27 | 2027/28 | 2028-29 | 2029/30 |
| Cumulative length of trunk main | km | 0 | 0 | 0 | 6 | 12 |

PCD payment

6.5. We propose to calculate our end of period PCD payment rate based on an average cost:

| PCD payment unit | Calculation | PCD payment (£m) |
|------------------|--|------------------|
| £m per km | Enhancement totex ÷ total length of main £170.137m / 12.000km We have excluded totex and length of main for our LWICA programme. | 14.178 |

6.6. We understand Ofwat will apply cost sharing as part of its draft determinations and the end of period reconciliation will occur with the totex reconciliation models, including the time value of money adjustment.

6.7. We propose the PCD payment should be calculated from the difference between forecast 2029/30 deliverable and actual 2029/30 deliverable. As per Ofwat's guidance, IN 23/05, we consider where the difference is due to schemes that are going to be delivered early in AMP9, this amount should be excluded.

Time incentive (TI)

6.8. We do not consider any Performance Commitments and associated ODI rates are applicable to this Enhancement Case. Accordingly we propose a time incentive to provide annualised protection.

6.9. For late delivery, we propose a time incentive payment rate based on the PCD payment:

| TI payment unit | Calculation | TI payment (£m) |
|-----------------|--|-----------------|
| £m per km | <i>PCD payment</i> × 3.5% £14.178m × 3.5% | 0.496 |

- 6.10. We propose the time incentive payment should be calculated from the difference between forecast deliverable and actual deliverable for each year of the AMP.

Protecting customers with the mains repairs Performance Commitment is not appropriate

- 6.11. The mains repairs Performance Commitment covers the number of mains repairs per thousand kilometres of a company's entire water main network (excluding communication and supply pipes). However, this Enhancement Case is only focusing on trunk mains that create a high risk for the flooding of basement properties, of which our highest risk mains are all located in London.
- 6.12. This subset of mains has higher than average costs due to several factors, for example, the complexity of excavations, traffic management costs and impacts to local population. The actual cost to rehabilitate a kilometre of trunk main is well in excess of the typical value of £1,565 per metre of distribution mains in London.
- 6.13. Therefore, we do not consider this PC appropriately protects customers from any under or non-delivery. Similarly, the ODI value does not recognise the benefits to those customers at high risk from basement flooding – and it would be inappropriate to apply this benefit to all mains, the vast majority of which present minimal risk to basement flooding.
- 6.14. Customers are not exposed to third-party funding risks as no third-party funding is required.

6. Adaptive planning

- 7.1. We have identified our best value pathway and the turning points from it considering alternatives.

Best Value Pathway

- 7.2. Our best value pathway involves a steady and increasing ramp-up of trunk main rehabilitation as the capability and capacity of our Capital Delivery function increases and we may take advantage of technological advances and efficiencies, to deliver more for our customers and communities AMP-on-AMP. This pathway is set out in the table below in terms of both km of mains rehabilitated and £ expenditure per AMP. This table excludes the AMP7 LWICA carryover in AMP8.

Table 12: Core pathway spend and km

| | AMP7 | AMP8 | AMP9 | AMP10 | AMP11 | AMP12 |
|-------------|------|------|------|-------|-------|-------|
| km | 15 | 12 | 31 | 62 | 94 | 129 |
| £(m) | | £170 | £398 | £558 | £761 | £940 |

Source: Thames Water

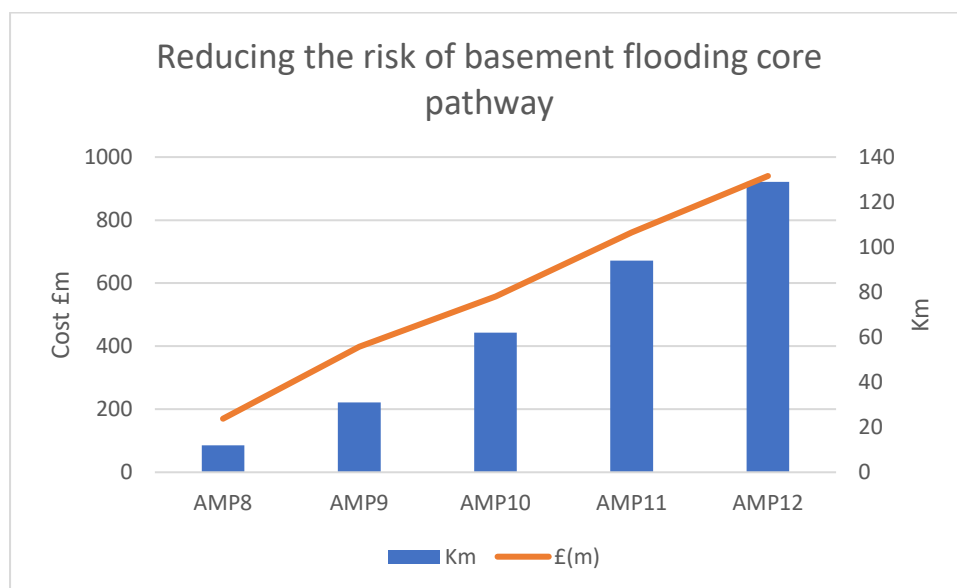
Table 13 - Assessment of core pathway

| Investment | Planning Horizon | Needed in all scenarios | Needed in most scenarios | Needed to keep future options open | Needed in the short term | Core Pathway (km) |
|--------------------------|------------------|------------------------------|--------------------------|------------------------------------|--------------------------|-------------------|
| Trunk Mains Renewal (km) | 2025-2030 | Yes | Yes | No | Yes | 12 |
| | 2030-2035 | Yes | Yes | No | No | 31 |
| | 2035-2040 | Yes | Yes | No | No | 62 |
| | 2040-2045 | Yes | Yes | No | No | 94 |
| | 2045-2050 | Yes | Yes | No | No | 129 |
| Total Cost | £m | £2,828 (£2,874m incl. LWICA) | | | | |

Source: Thames Water

Our chosen core pathway addresses all 608km of 'very high' or 'high risk' mains by 2050, of which we estimate 343km will require rehabilitation.

Figure 24: Reducing the risk of basement flooding core pathway

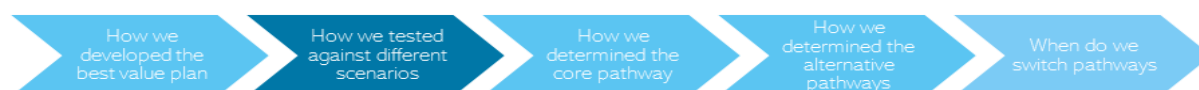


Source: Thames Water

How we defined scenarios

7.3. The chevron graphic below shows how we have structured our narrative on adaptive planning. Having detailed how we developed the best value plan in previous sections, in this section we focus on the subsequent four chevrons, starting with the scenario testing.

Figure 25: Adaptive pathway approach



Source: Thames Water

7.4. We considered ‘common reference scenarios’ to test against our preferred plan. 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). We focused on technology and climate change scenarios, as others were assessed to have a negligible impact on the risk of basement flooding resulting from a failure in our trunk main network.

7.5. Below, we summarise how we defined the forecast for the different scenarios under technology and climate.

Technology Scenarios

7.6. The two key considerations for how a low or high technology scenario might impact our 25-year delivery strategy are trunk main rehabilitation methods, and asset condition assessments.

Table 14: Summary of technology scenarios

| | Low Technology | High Technology (Core Pathway) |
|------------------------------------|---|--|
| Description | <p>Rehab methods (and therefore unit rates) will remain largely unchanged in the short-mid term, using a similar combination of replacement and sliplining, as per the AMP8 costed schemes.</p> <p>More accurate, reliable and precise asset condition information through innovative inspection methods enable a more targeted risk-based investment programme from 2040 onwards, allowing us to targeting only the poor condition sections of pipework and leave 'healthy' sections of pipe in-situ. This results in a one-off/step-change in efficiency from 2040 onwards.</p> | <p>Innovation will increase significantly within the industry throughout the next 25 years, providing consistent opportunities for innovative no-dig / low-dig rehab methods. This will result in more significant cost efficiencies AMP-on-AMP from 2030 onwards.</p> <p>More accurate, reliable and precise asset condition information through innovative inspection methods enable a more targeted risk-based investment programme from 2035 onwards, allowing us to targeting only the poor condition sections of pipework and leave 'healthy' sections of pipe in-situ. This results in a one-off/step-change in efficiency from 2035 onwards.</p> |
| Rehab Methods Impact | AMP8 unit rates (£/km) are unchanged. | 10% AMP-on-AMP cost efficiency from the initial AMP8 unit rate (£/km), resulting in a 40% efficiency over the 25 year period |
| Asset condition information Impact | One-off 20% efficiency at 2040 | One-off 20% efficiency at 2035 |
| Combined Impact | ~20% efficiency, across the entire 25 year period. | ~50% efficiency, across the entire 25 year period. |

Source: Thames Water

Climate Change Scenarios

- 7.7. The key consideration for how a low or high climate change scenario might impact our 25-year delivery strategy is a significant change in the likelihood of failure of our assets, caused by frequency and scale of extremities in wetting and drying cycles, as well as drought risk and subsequent change in soil moisture deficit.

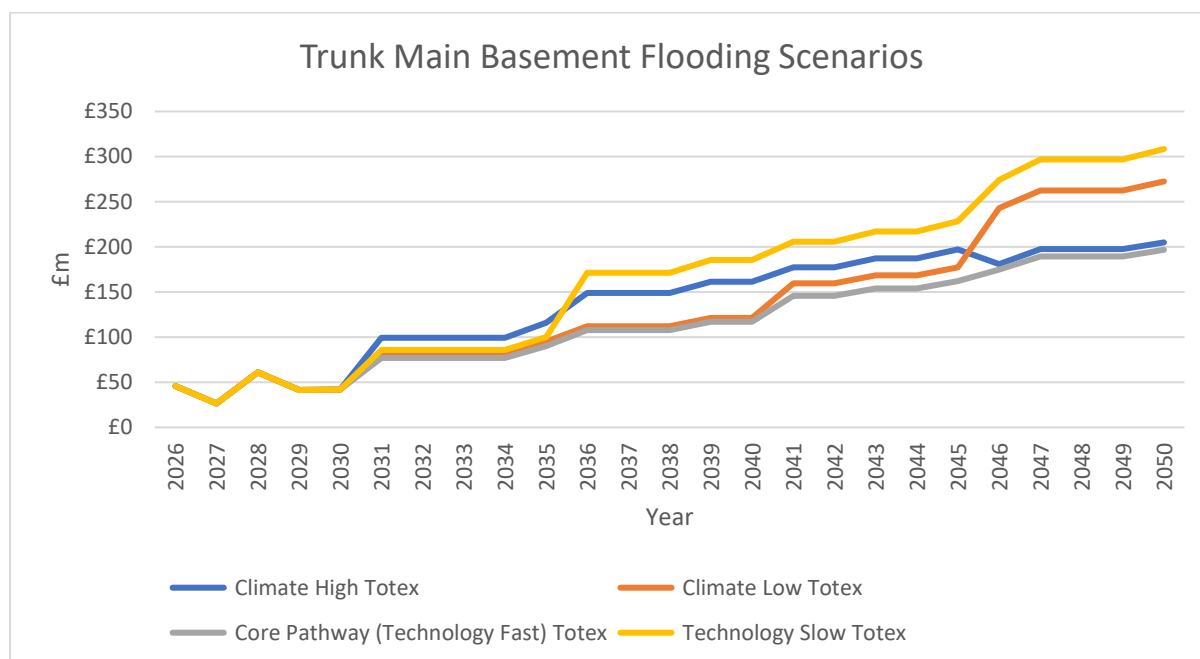
Table 15: Summary of climate change scenarios

| UKCP18 probabilistic projections | Low Climate Change (RCP 2.6) | High Climate Change (RCP 8.5) |
|----------------------------------|--|---|
| Description | <p>Slower increase in drought risk and subsequent change in soil moisture deficit.</p> <p>Lesser increase in extremities in wetting and drying cycles. This results in a slower increase in the likelihood of pipe failure overtime than assumed within our initial strategy. Whilst this will not impact the scope of our trunk mains rehabilitation plan, it may impact the timing (i.e. if there are other priorities across the business in the short-mid-term we may choose to adopt a more 'back-loaded' plan for our high risk trunk mains.</p> | <p>Increased drought risk and subsequent change in soil moisture deficit results in pipe failure. Greater extremities in wetting and drying cycles lead to greater soil movement, causing pipe systems to move increasing burst frequency.</p> <p>This results in a greater increase in likelihood of pipe failure overtime than assumed within our initial strategy and could result in increased public scrutiny which in turn adjusts our risk appetite as a business. This is unlikely to change the scope of our trunk main replacement plan but may impact the timing, i.e. we may choose to have a more front-loaded plan for our high risk trunk mains.</p> |
| Impact | ~8% decrease across AMPs 10 & 11 and ~10% increase in AMP 12 | ~22% increase across AMPs 9 & 10 scope, ~2% increase in AMP 11 and ~18% decrease AMP 12. |

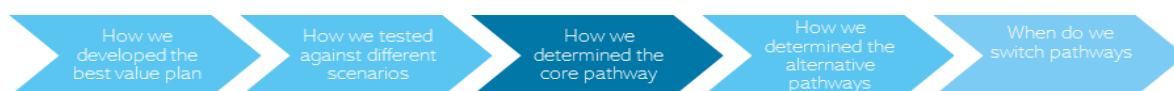
Source: Thames Water

- 7.8. Based on the information available we have plotted below the likely impact each scenario would have on our best value pathway. All scenarios follow the same trajectory during AMP8, as we assume no major changes to available technology and no major changes to climate.
- 7.9. Over the longer term, the low technology scenario can be seen to have the greatest impact on delivery of the plan – this assumes we won't achieve the same level of efficiency as our best value plan to deliver the same level of basement flood protection.

Figure 26: Spend on trunk mains to reduce risk of basement flooding scenarios

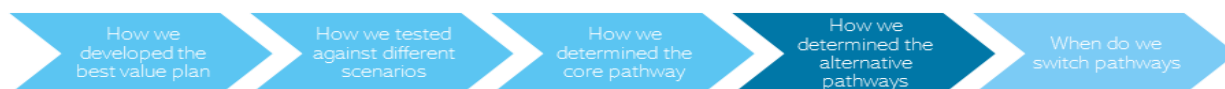


Source: Thames Water



7.10. Based on the results of our testing against the common reference scenarios, we identified a ‘core adaptive pathway’ which is also our best value adaptive pathway. This drives a programme of no- and low-regret investments, as per Ofwat’s LTDS guidance. Our core pathway is assessed from high technology scenario, under current climate change forecasts, assuming we use the best technology available when carrying out replacement work.

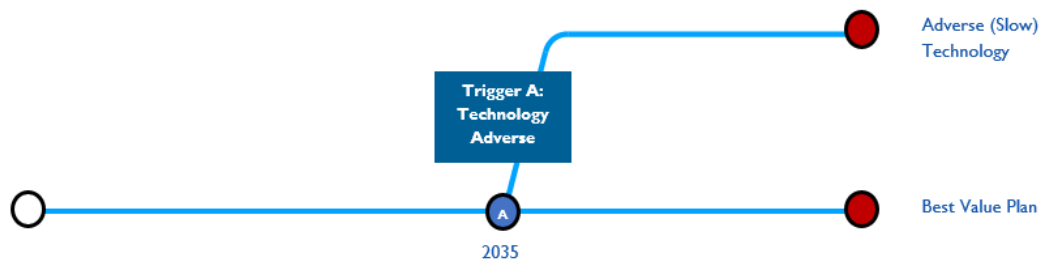
7.11. In our best value pathway, more accurate, reliable and precise asset condition information through innovative inspection methods will enable a more targeted risk-based investment programme from 2035 onwards, allowing us to target only the poor condition sections of pipework and leave ‘healthy’ sections of pipe in-situ. If this benefit is not felt until later in the 25-year timeframe, it will present a significant inefficiency to our delivery programme.



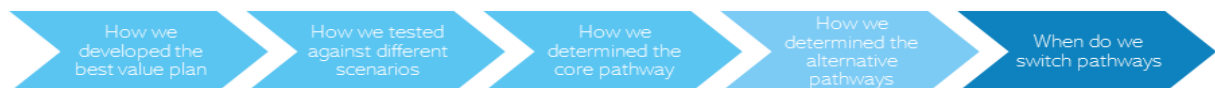
7.12. Having established our best value plan (and core pathway) we developed and tested alternative pathways that meet our long-term ambition over a range of plausible futures. For simplicity we include our most adverse pathway for comparison which uses a low technology scenario.

- 7.13. We determined the low technology scenario to have the most material impact on the best value pathway for our LTDS. This impact is primarily due to long-length asset condition assessments benefiting our investment programme at a later point in time (2040) than assumed in our best value pathway (2035).

Figure 27 - Best value pathway



Source: Thames Water

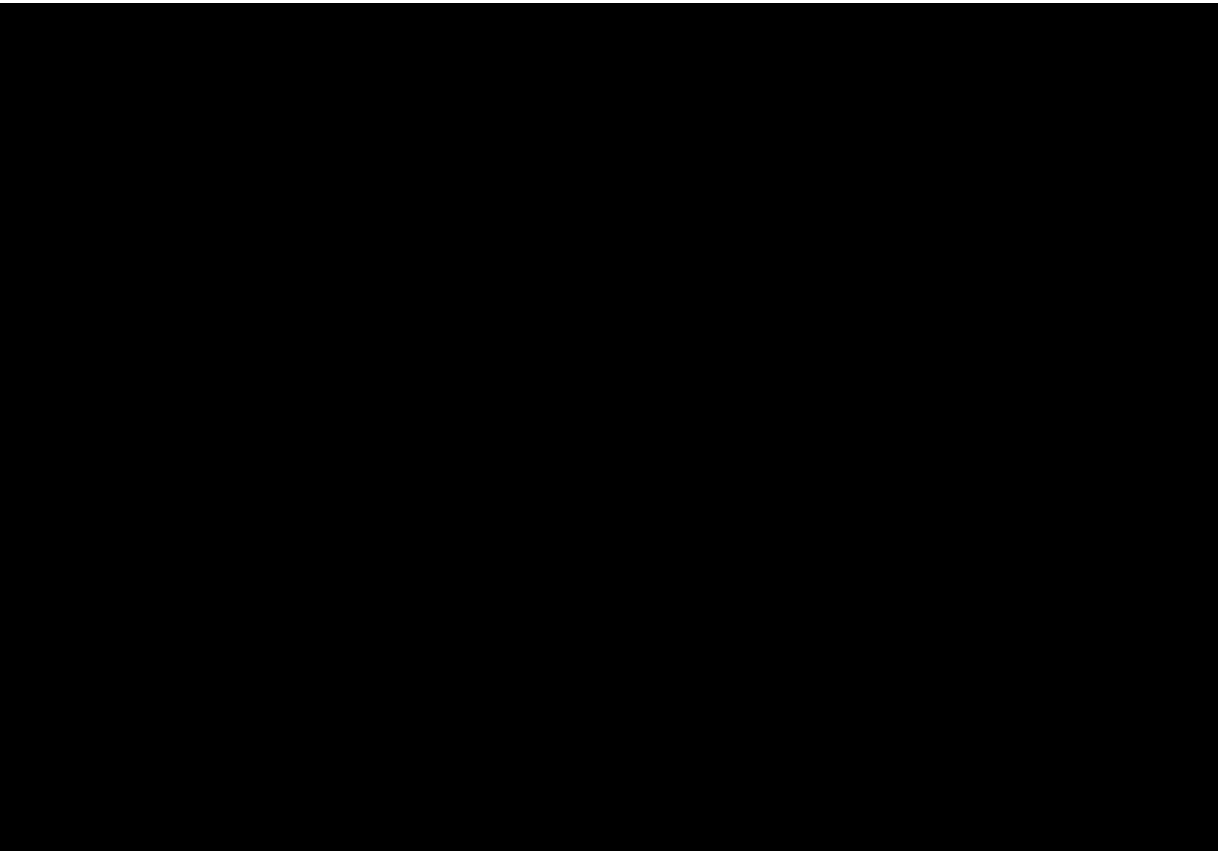


- 7.14. As technology change forecasts drive most change to the best value plan, these forecasts drive a switch to a different pathway. There are no specific one-off ‘hard’ triggers for considering moving to an alternative pathway. Rather, what will put us onto a different path is the delay in emergence of new long-length condition assessment and rehabilitation technologies.
- 7.15. The work we are proposing to undertake during AMP8 is ‘no regrets’. We are tackling trunk mains with the highest risk of flooding basement properties.

[Redacted]

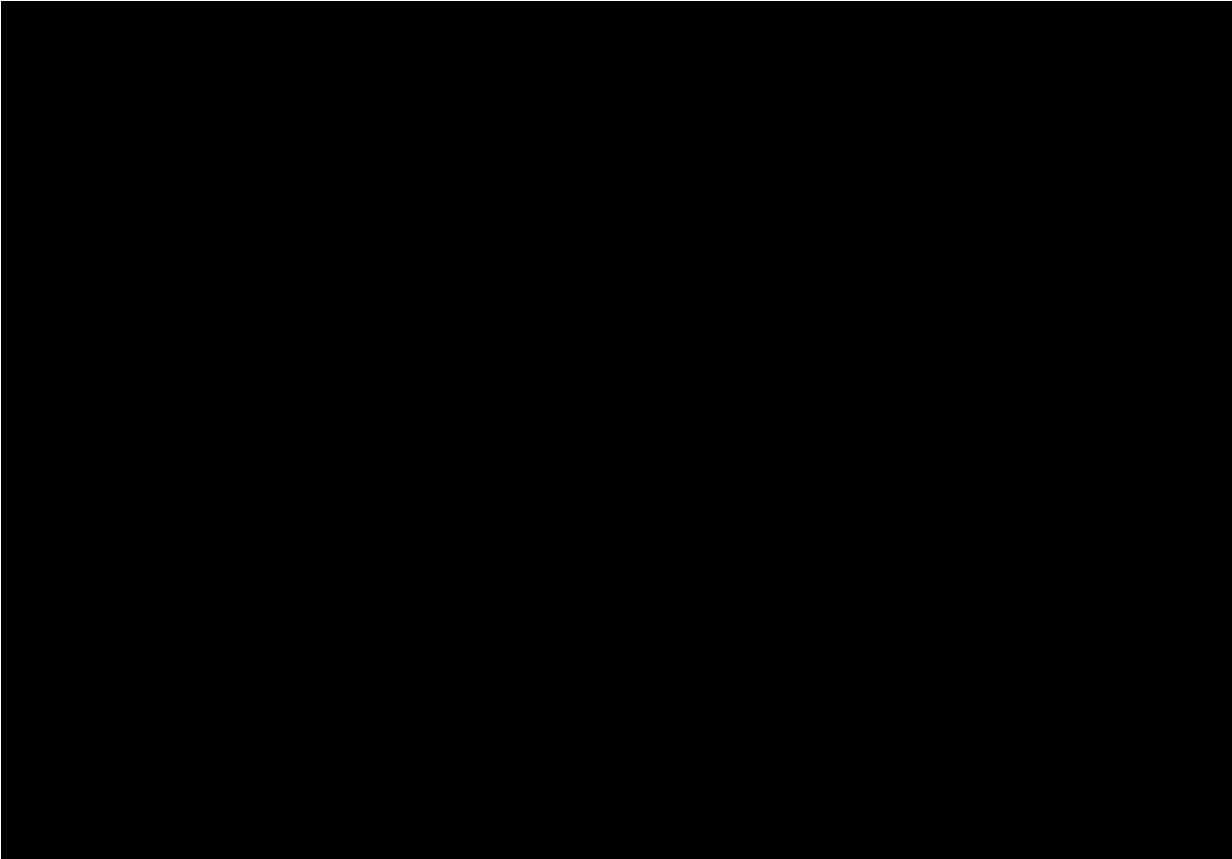
[Redacted]

[Redacted]



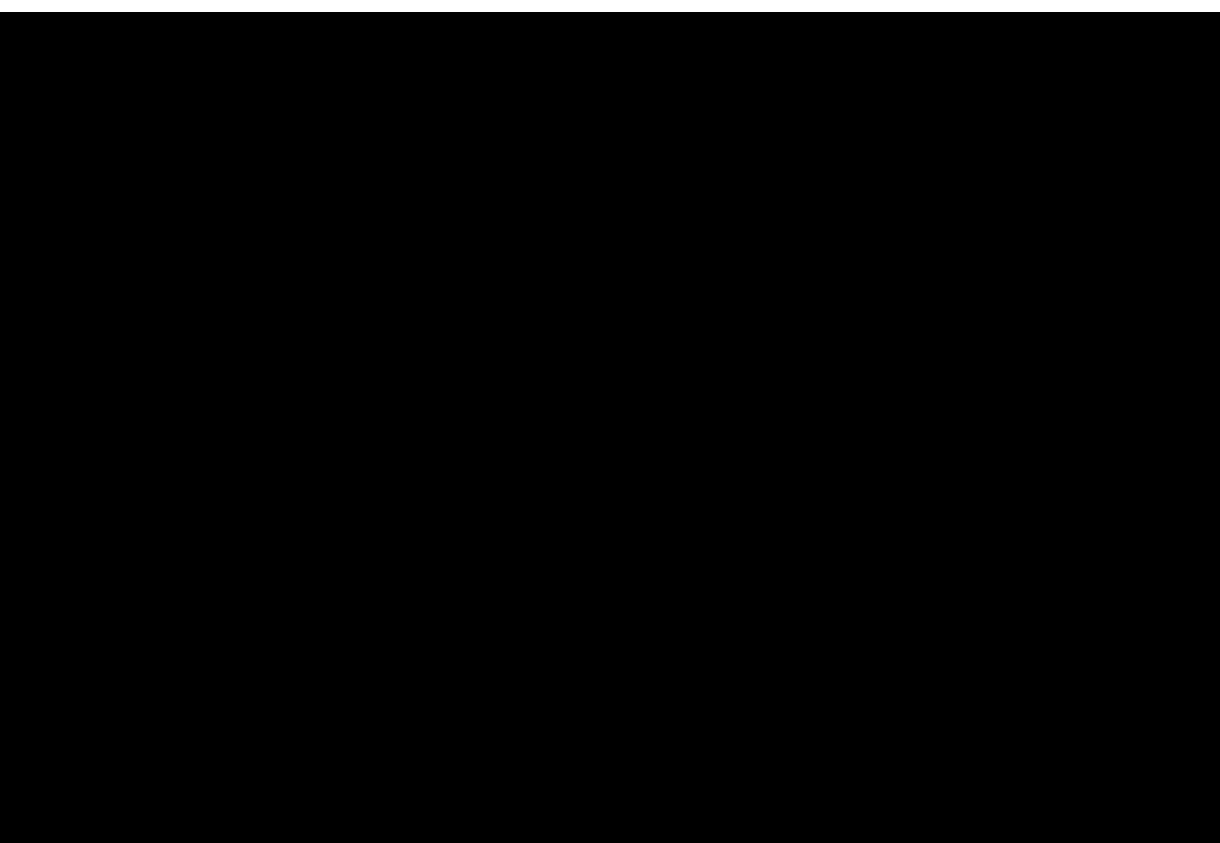
Source: Thames Water

[Redacted]



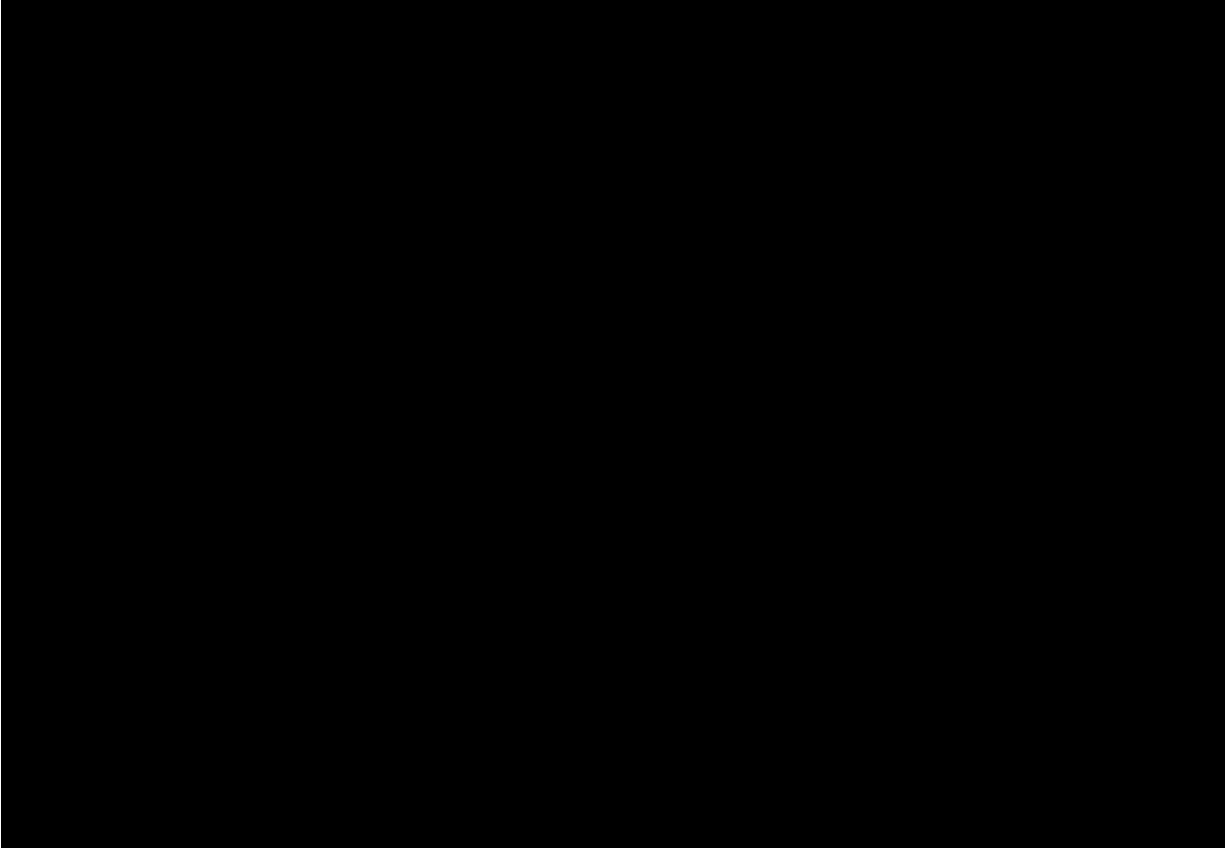
Source: Thames Water

[Redacted]



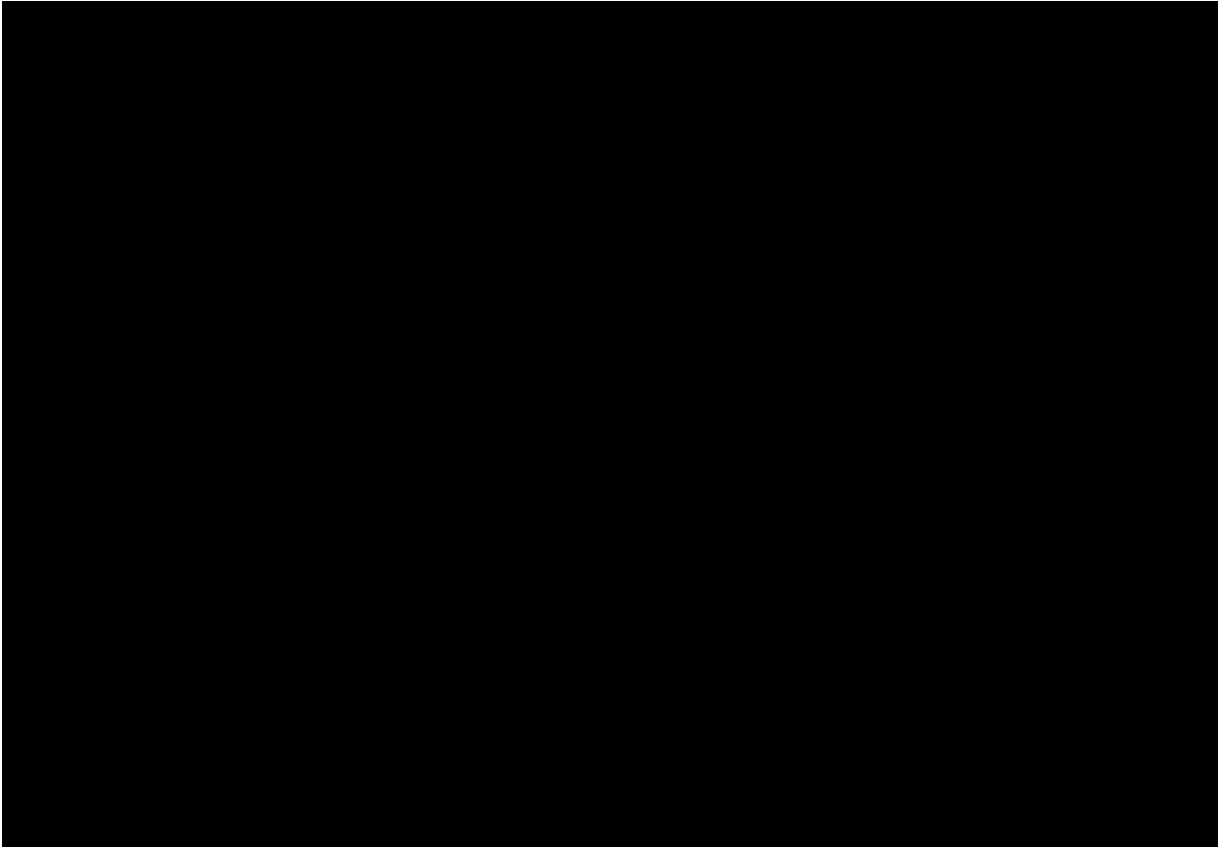
Source: Thames Water

[Redacted]



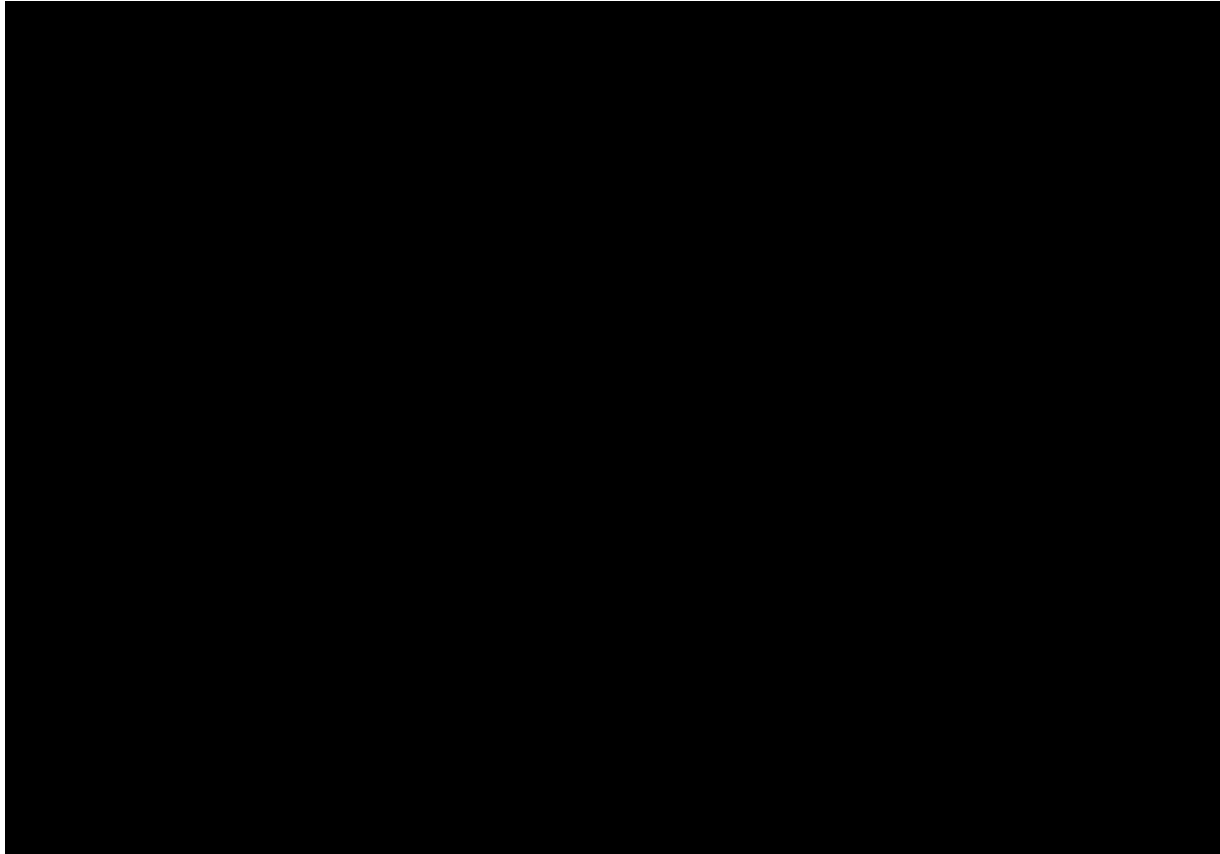
Source: Thames Water

[Redacted]



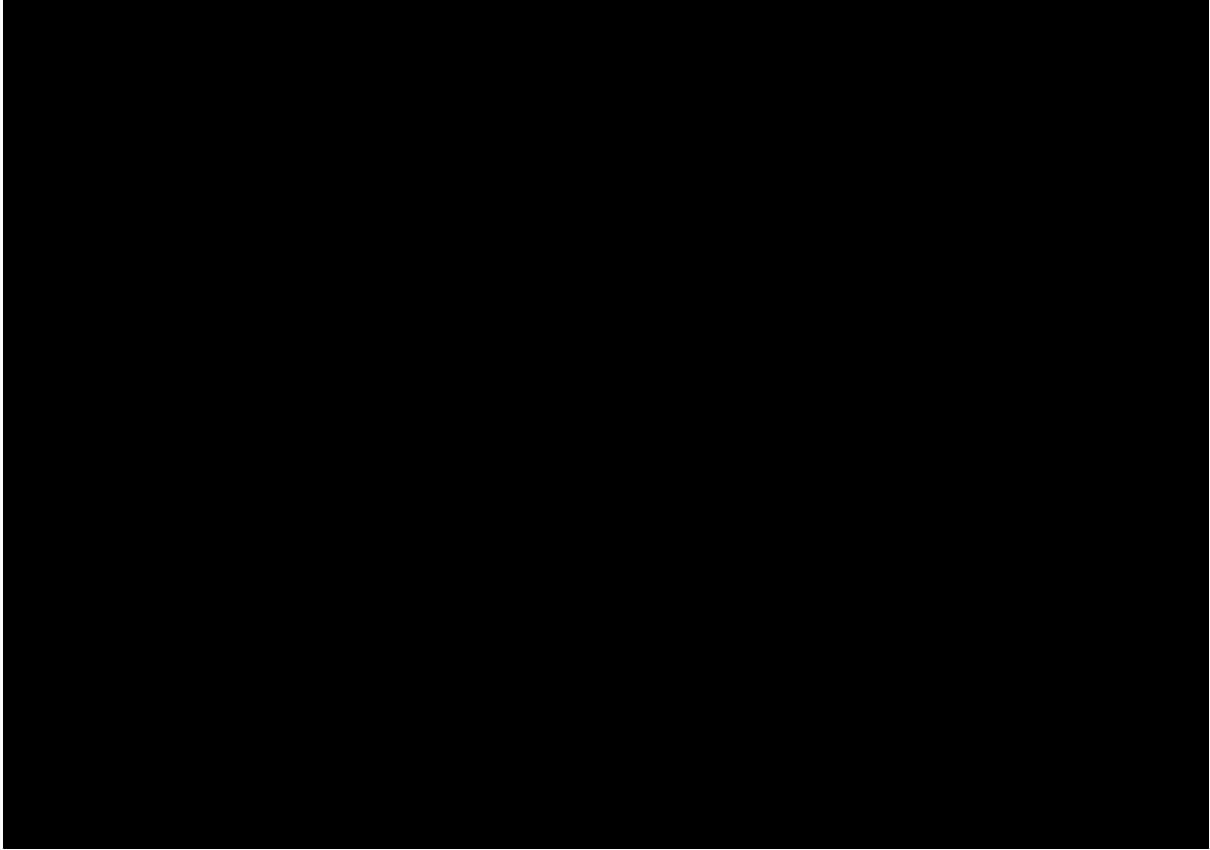
Source: Thames Water

[Redacted]



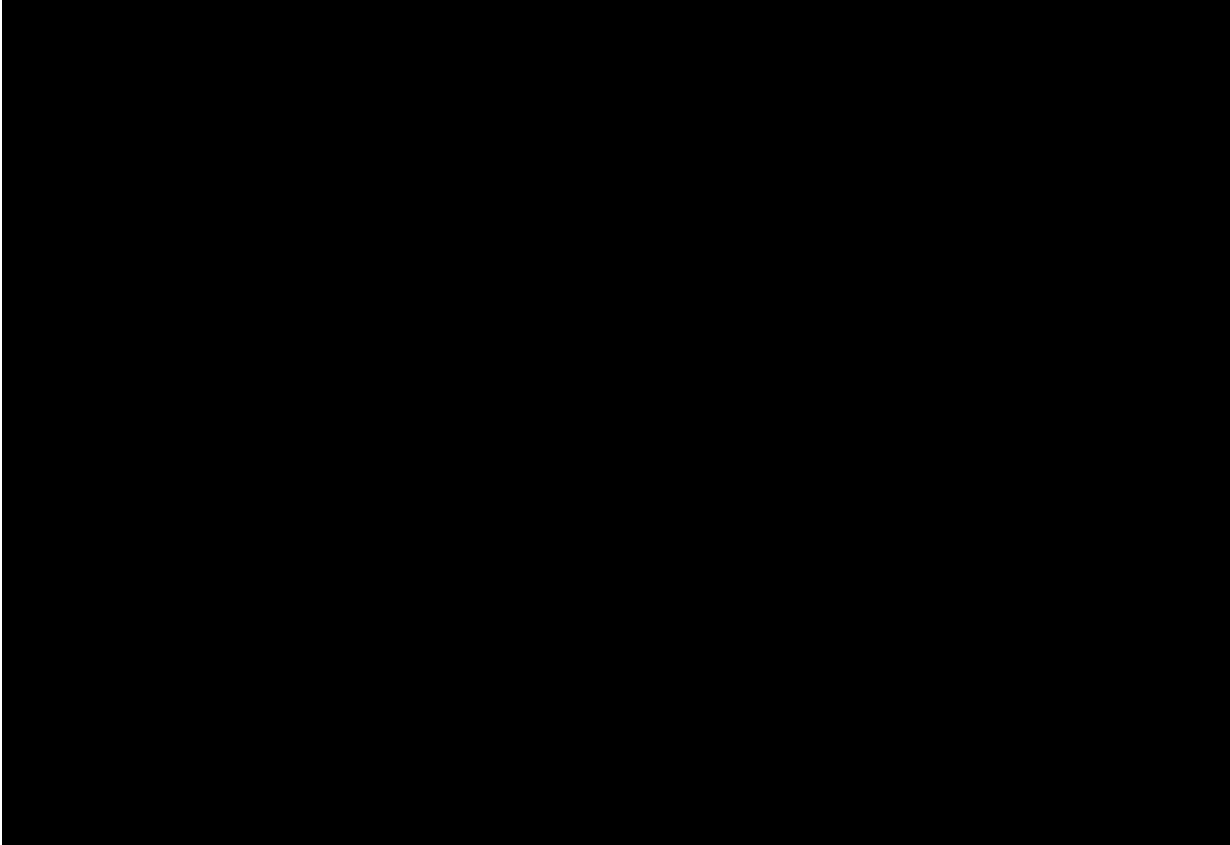
Source: Thames Water

[Redacted]



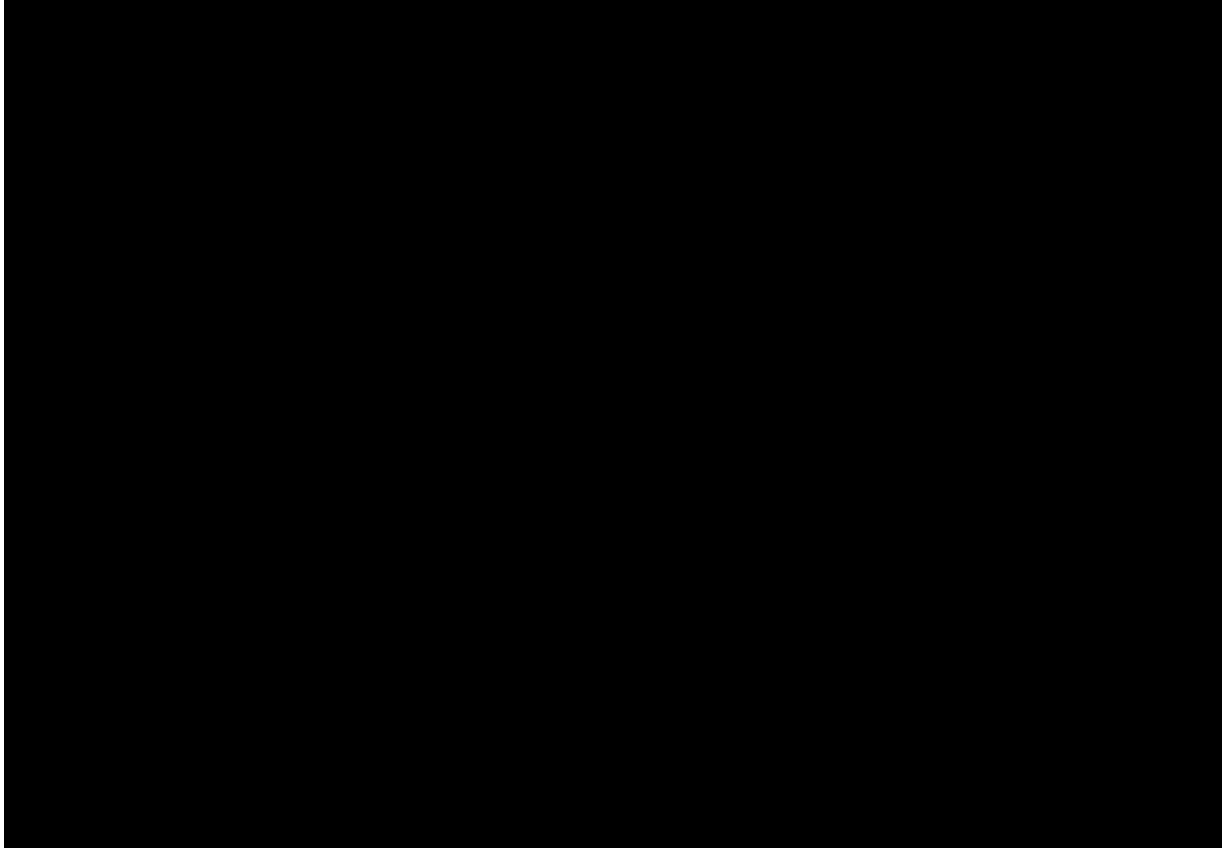
Source: Thames Water

[Redacted]



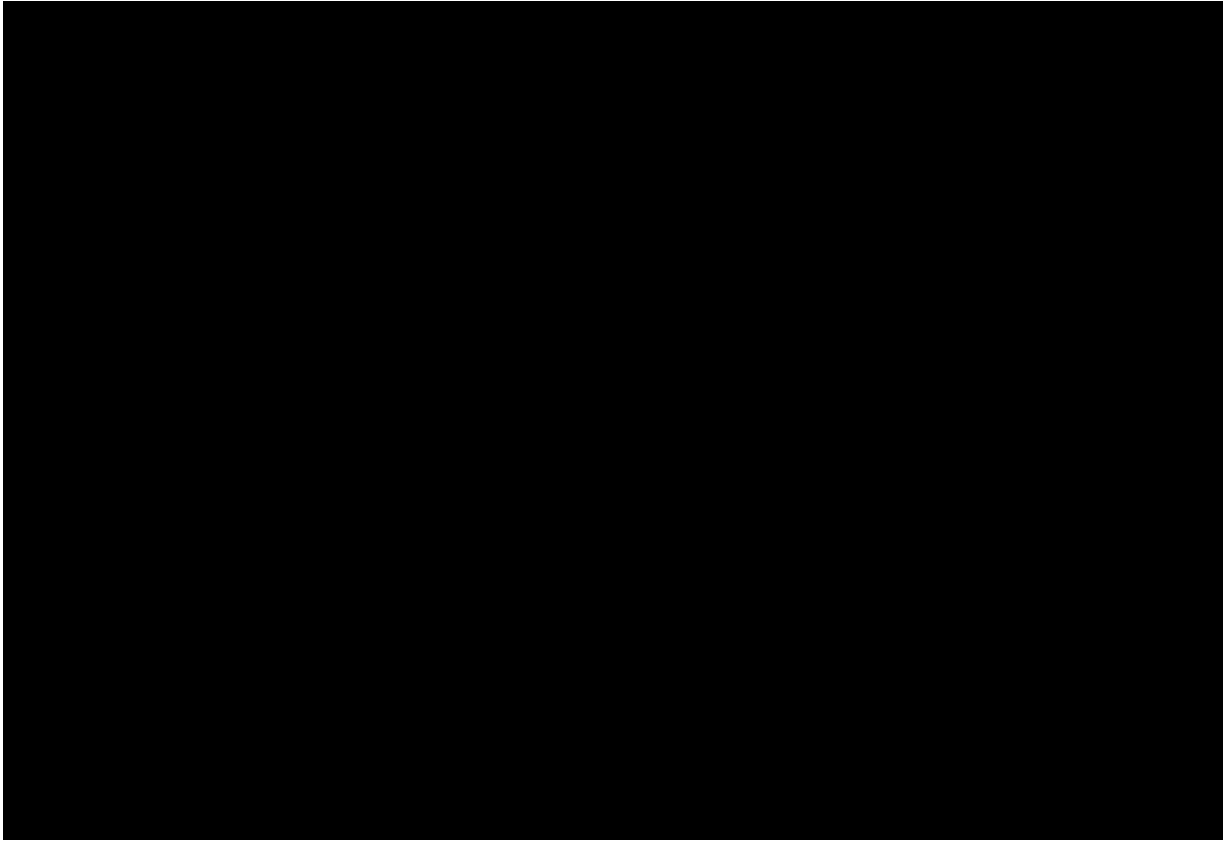
Source: Thames Water

[Redacted]



Source: Thames Water

[Redacted]



Source: Thames Water

[Redacted]



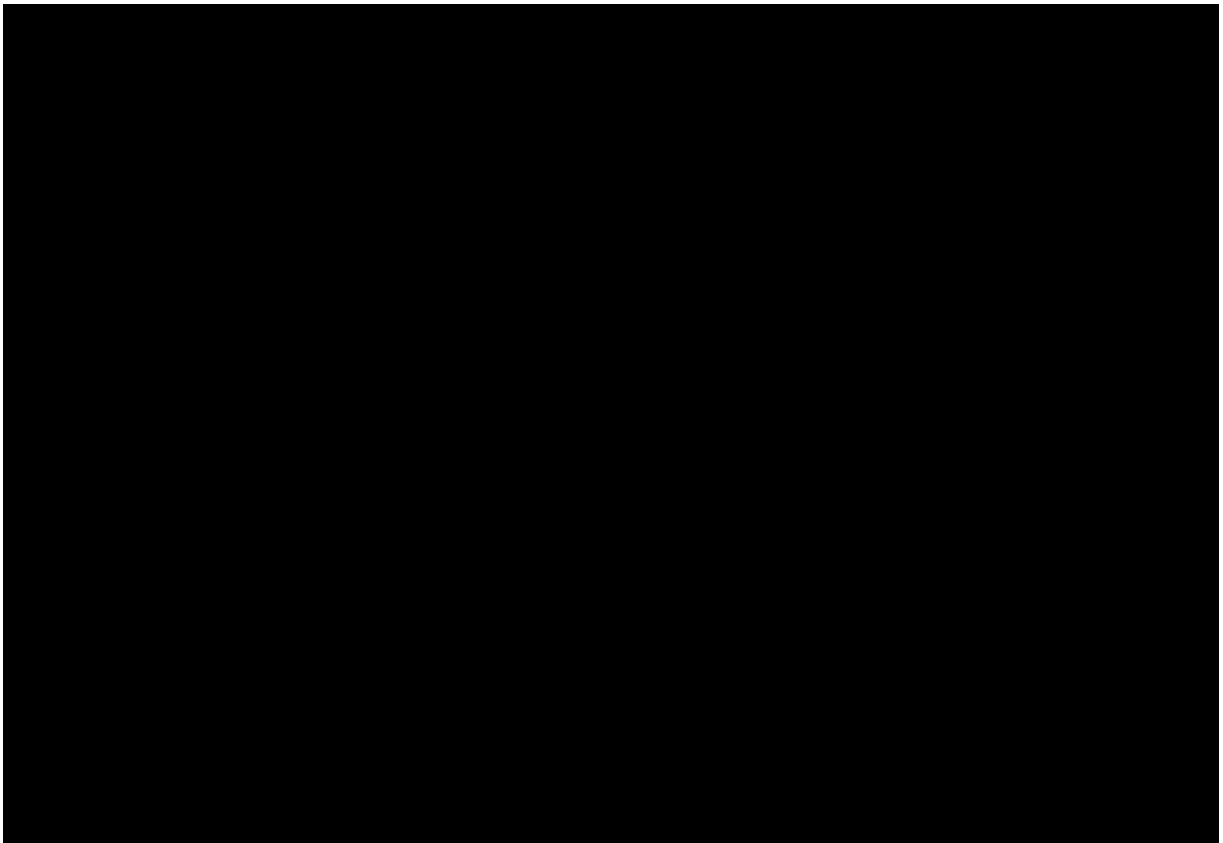
Source: Thames Water

[Redacted]



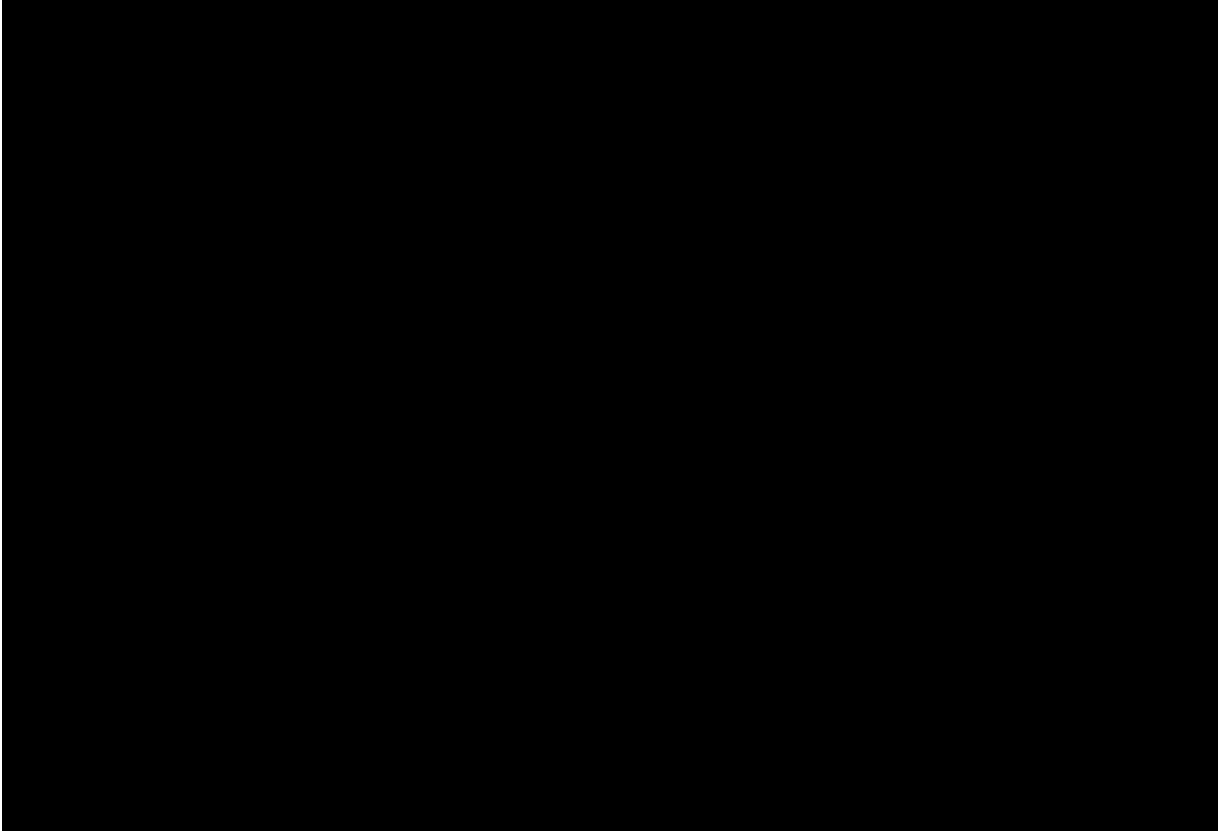
Source: Thames Water

[Redacted]



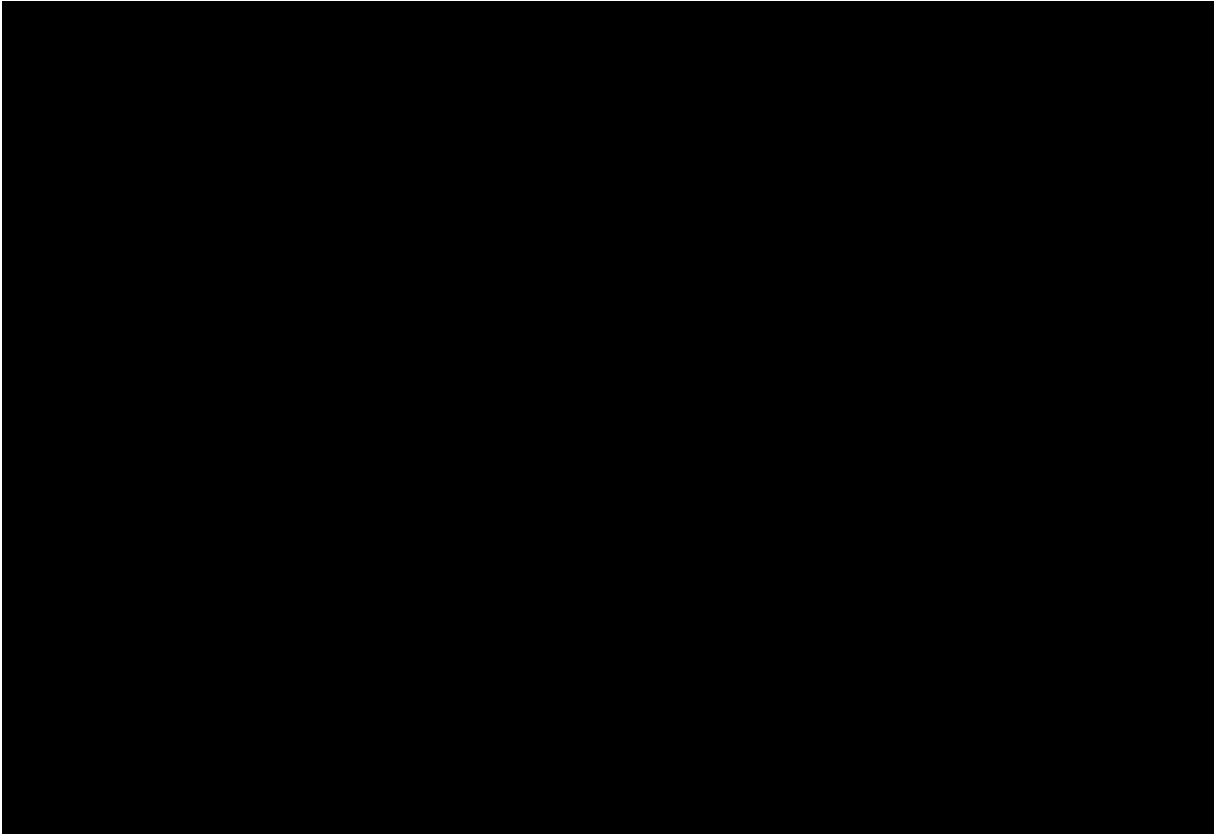
Source: Thames Water

[Redacted]



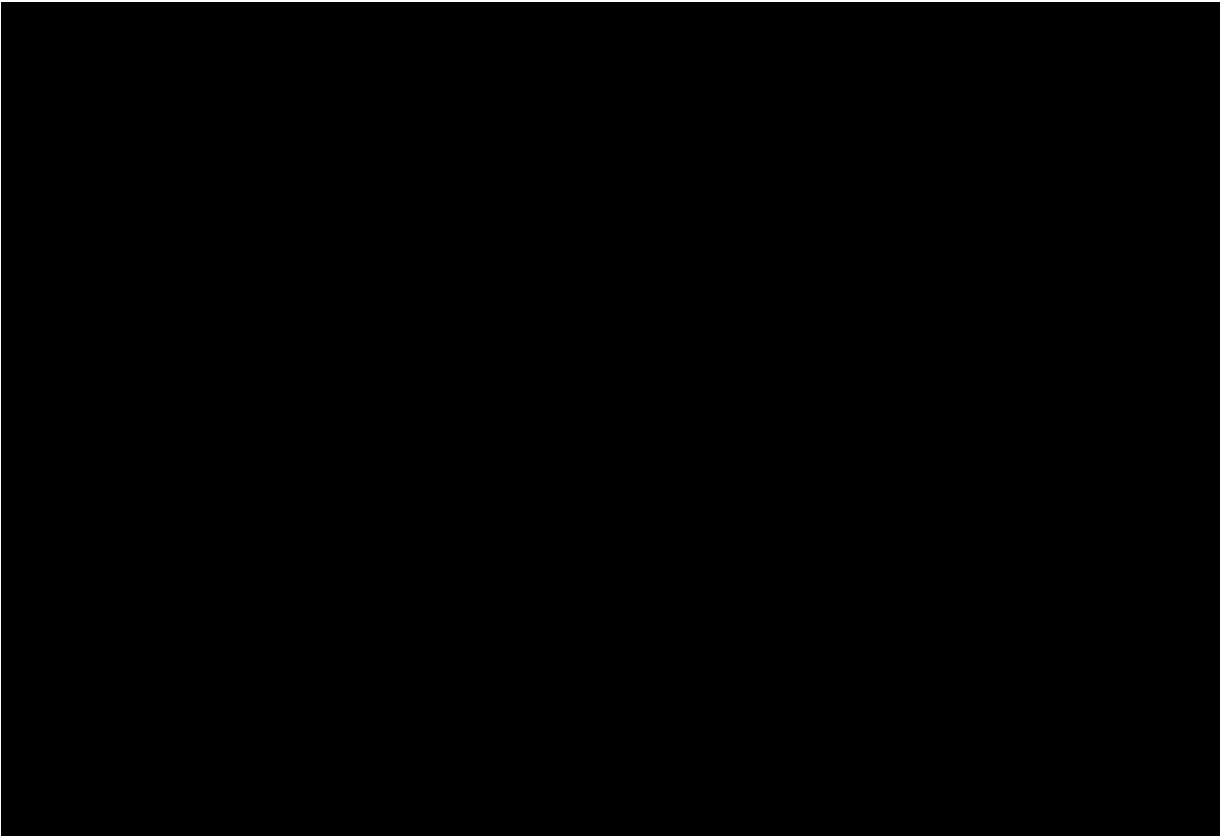
Source: Thames Water

[Redacted]



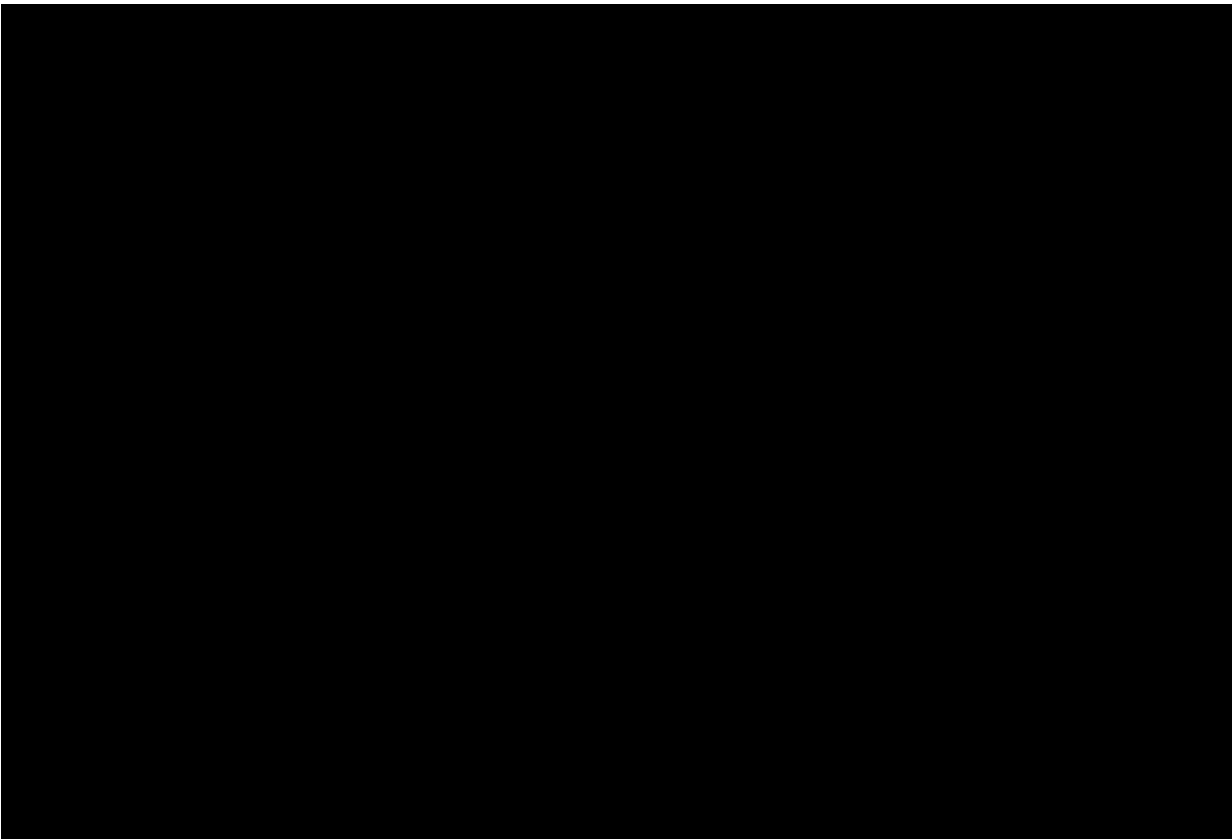
Source: Thames Water

[Redacted]



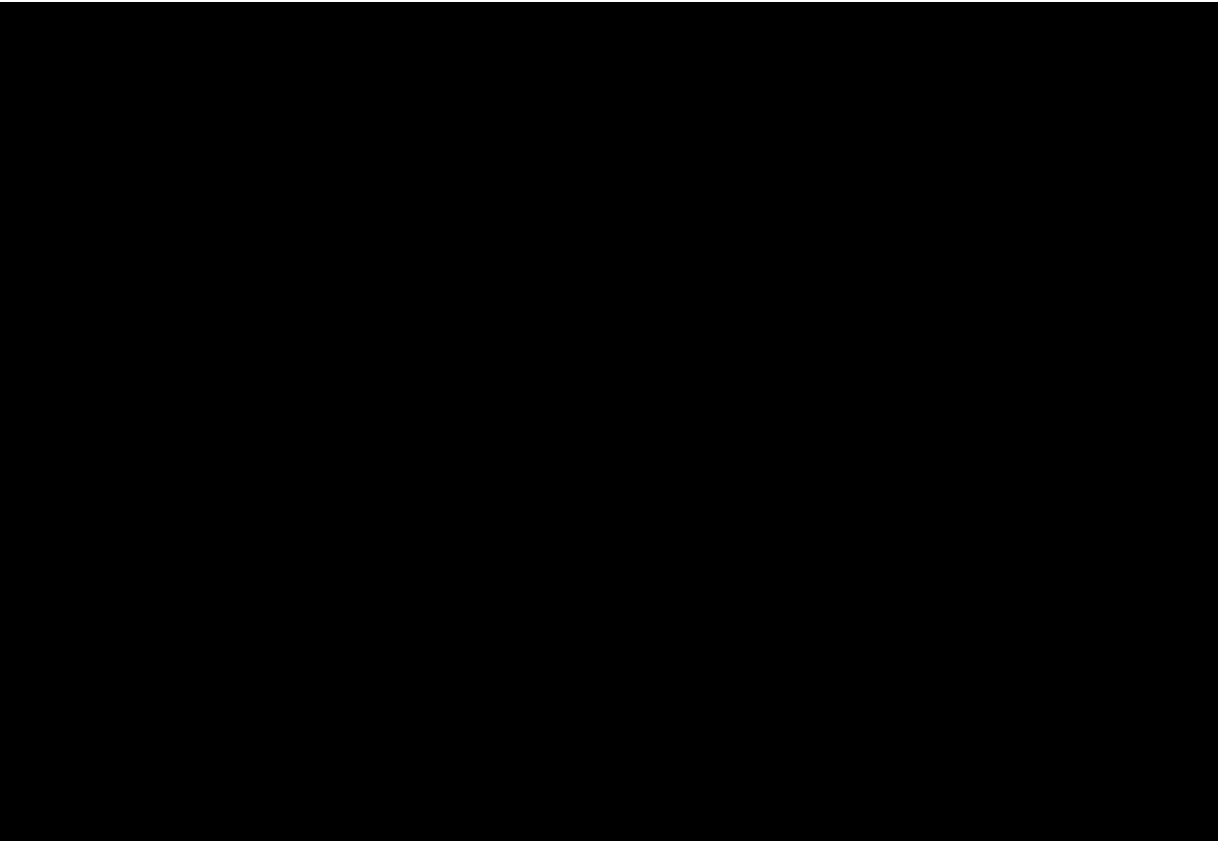
Source: Thames Water

[Redacted]



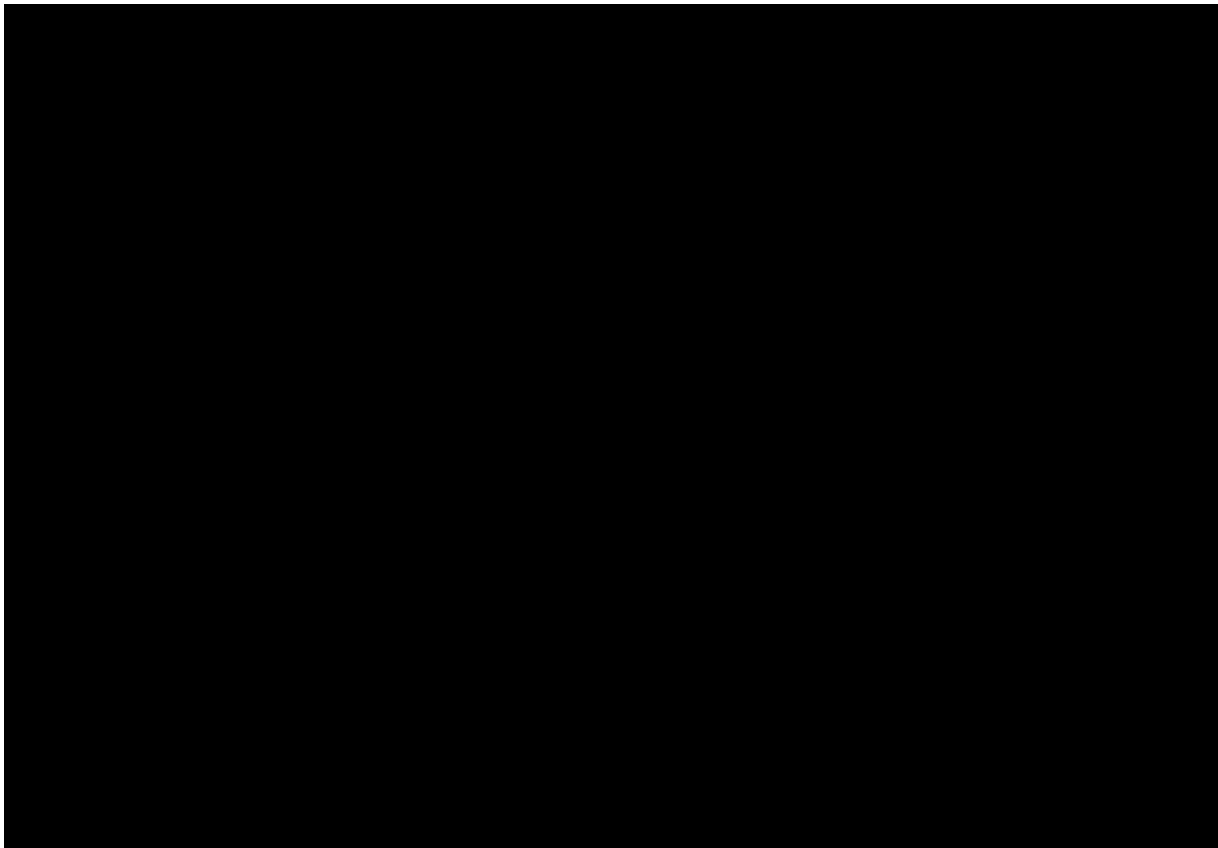
Source: Thames Water

[Redacted]



Source: Thames Water

[Redacted]



Source: Thames Water

Annex B – Case study on response times to major bursts

- 8.1. On the 8th of October 2019 the Finsbury Park: Maiden Lane Principal Trunk Main B 36" suffered a large longitudinal pipe failure [REDACTED]. The pipe was made from cast iron and laid in 1894.
- 8.2. This section of main is considered 'High Risk' with a high probability of failure and is in the top 18% of trunk mains risk.
- 8.3. The flood impact of the event was around 100 properties; 45 properties had to be rehoused.
- 8.4. Timeline of event:
 - A 36" main burst in [REDACTED], reported by passer-by, widespread customer calls due to low pressure/no water and flooding in area.
 - From 0745: Significant Twitter posts of flooding
 - 0758: Requested flood vehicle to attend site
 - 0800: 3 NST's enroute to investigate (first arrive 0843)
 - 1527: Isolation complete, pressure out of Stoke Newington shaft return to normal and flow from the burst has dropped.
 - To isolate the burst and due to a let-by on 1 of the key valves – the total mains isolation became 9x valves:
 - Western section: 1x line valve (CR: 486866) was required - There was a parked car on it which Police eventually helped remove.
 - Middle section (Somerville PRV): 1x valve upstream of PRV (CR: 760962) was required. No issues shutting this.
 - Eastern section near Stoke Newington shaft: 1x line valve (CR: 762787) and 1 bypass (CR: 762786) required.
 - Bypass was shut successfully but there was a let-by on the line valve. This extended the shut to include 4 additional valves (762785, 762784, 481285, 481305) which once closed, isolated the burst.
 - The last checks on CR762787 and CR762786 were in July 2016 and valves were reported as missing. Whilst valve checks would not have found the let-by, the missing status is being investigated.
 - Pressures in the zone started recovering once burst was isolated.
 - The 36" trunk main that failed in the Queens Drive failure flooding event was operating at a flow of c.200l/s and a pressure of 4.8 Bar.
 - There was some evidence of a previous leak repair. The closest basement properties were located within 15 meters of the burst point and are therefore likely to have been inundated within a few minutes.



It's everyone's water