



National Audit Office

Report

by the Comptroller
and Auditor General

Department for Environment, Food & Rural Affairs

Review of the Thames Tideway Tunnel

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Department for Environment, Food & Rural Affairs

Review of the Thames Tideway Tunnel

Report by the Comptroller and Auditor General

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Sir Amyas Morse KCB
Comptroller and Auditor General
National Audit Office

28 February 2017

This report examines the evidence base supporting the decision to proceed with the Thames Tideway Tunnel, as well as progress achieved to date and how risks are being mitigated.

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Summary

1 The Thames Tideway Tunnel (the Tunnel) is a major project to construct a sewer tunnel running 25 kilometres from Acton in West London to Abbey Mills in East London, intercepting storm sewage overflows which would otherwise discharge into the Thames. In June 2014 we published *Thames Tideway Tunnel: early review of potential risks to value for money*.¹ Our report outlined six areas that we considered most critical to achieving value for money for customers and the taxpayer. As the Tunnel is not expected to be fully operational until 2024, we plan to update Parliament on progress at various times: this review is the second of those updates.

Background

2 Spills from Combined Sewer Overflows (CSOs) along the Thames degrade water quality and the environment of the tidal reaches of the Thames (the Tideway). In 1991, the European Union adopted the Urban Waste Water Treatment Directive (the Directive), aiming to protect the environment from waste water discharges, with member state compliance expected for large cities by 2000. The Directive does not specify thresholds for, or provide detailed guidance on, compliance for CSOs. In 2006, the European Commission issued a 'reasoned opinion' stating that the UK was failing to comply with the Directive's requirements for London. In 2010, the Commission started legal proceedings with the Court of Justice of the European Union, which in 2012 found the UK to be in breach owing to the frequency of spills from CSOs along the River Thames. This has meant that the UK was, and still is, at risk of infraction fines if the problem is not addressed.

3 The Department for Environment, Food & Rural Affairs (the Department) has overall policy responsibility for water and sewerage in England, and overseeing the English regions' compliance with European environmental directives.

¹ Comptroller and Auditor General, *Thames Tideway Tunnel: early review of the potential risks to value for money*, Session 2014-15, HC 168, National Audit Office, June 2014.

4 Work has been ongoing since 2000, in part, aimed at achieving compliance with the Directive. Thames Water, a privately-owned company, is responsible for sewerage infrastructure in London, and for developing a solution to the problem of overflows. In 2000, it began funding research into a solution which reported in 2005. Because of implications for public policy, the Department developed strategic objectives for a solution: to secure compliance with the Directive, and to improve the environmental quality of the Tideway by reducing sewage overflows. The Department announced support for the Tunnel as a solution in 2007. In 2014, the Department added a third objective: to ensure sufficient strategic sewer capacity to accommodate London's growth for at least the next hundred years.

5 The Department intends that the project will be delivered and financed privately, although it has made a contingent financial support package available to secure this. Thames Water has planned the Tunnel and proposed its initial design; its customers will meet the costs through their water bills. Since our report in 2014:

- a specially-created private company, Bazalgette Tunnel Limited (Bazalgette) – trading as 'Tideway' – has successfully bid to design, build, own, maintain and finance the Tunnel;
- a regulatory framework has been established covering Bazalgette;
- the government has provided a package of contingent financial support – the Government Support Package (GSP);
- the project has received development consent; and
- Bazalgette started work on various sites during 2016. The Department expects tunnelling to be completed by 2021, and fully operational in 2024 at the latest.

Scope of this report

6 In this report we provide an update on developments since June 2014, including programme progress, and cost estimates. We examine how the Department and the Environment Agency have managed risks in areas which are now substantively complete, particularly in setting objectives and appraising options.

7 In 2014, we did not review the evidence base supporting the decision to build the Tunnel to avoid influencing the outcome of ongoing competitions for the construction and financing of the Tunnel. We now look at the process for developing standards, and for appraising options; the strength of the underlying evidence base (including analysis and quality assurance arrangements); and evidence on the prospects that the Tunnel will deliver the Department's objectives. We look at the risks to customers and the taxpayer which will need to be managed by the public sector to protect value for money during the construction phase. It is too early to form a value-for-money conclusion on the whole project but this report, together with our 2014 report, outlines what we would expect to see when the project is complete.

Key findings

Setting objectives and appraising options

8 After the Directive in 1991, it took a considerable time to develop measurable standards and to appraise options capable of meeting those standards. As the Directive does not specify thresholds for compliance, the Department endorsed standards which the Environment Agency and Thames Water developed. Between 2000 and 2005, the Thames Tideway Strategic Study Steering Group analysed the impact of overflows, proposed environmental objectives, and criteria to define satisfactory performance against those objectives. This resulted in threshold-based standards for dissolved oxygen levels, and rules defining unsatisfactory CSOs along the Tideway which solutions would have to address. With the Department's agreement, Thames Water used these criteria in its appraisal of potential solutions, which concluded in 2010 (Figure 2 and paragraphs 1.3, 2.2 to 2.4 and 2.12 to 2.14).

9 The Department's objectives were broader than simply complying with the Directive, and this is reflected in the criteria used to appraise potential solutions.

We have two observations on these criteria:

- a The evidence was more robust for some criteria than others.** We found that the dissolved oxygen standards were supported by a rigorous scientific approach, which was favourably peer-reviewed by an independent academic and comparable to other English standards for environmental regulation. Thresholds for identifying unsatisfactory CSOs were based primarily on the Environment Agency's judgement which it only reviewed internally (paragraphs 2.7 and 2.8).
- b There was a degree of contingency in the criteria used to test whether the options considered complied with environmental standards.** The Environment Agency agreed with Thames Water that a maximum of four spill events in a modelled 'typical year' would deliver satisfactory environmental performance and compliance with the Directive. The Tunnel is designed to achieve this 'four spills' criterion. Data from 2016 suggests that the number of spills can exceed this threshold without any breaches of the dissolved oxygen standards, and some European Union member states have set less conservative maximum spill thresholds. The Department considers that inferences should not be made from a single year of data, and that thresholds adopted by other member states to demonstrate compliance are not relevant comparators, because of differences in the nature of overflows and water areas affected. The Department considers that the 'four spills' level of protection reflects the Government's aim to achieve its environmental and legal objectives well into the future, having regard for the likely impacts of population growth and climate change (paragraphs 1.7, 2.4, 2.11 and 2.16).

10 In 2007, the Department endorsed the Tunnel based on Thames Water's assessment that it was the lowest-cost option capable of achieving its objectives by 2020. We found options were appraised primarily based on their ability to achieve the dissolved oxygen standards. Our review found a wide range of options had been considered although, after the Department's 2007 decision, Thames Water's analysis of alternatives was less detailed; its costing of alternatives was not independently scrutinised; and combinations of alternative technologies were not appraised. The Department reviewed its position and concluded in 2014 that delaying the Tunnel to consider alternatives further would likely increase the risk of fines for breaching the Directive (paragraphs 2.12, 2.15, 2.16 and 2.19).

11 The Department and the Environment Agency did not fully explore uncertainty in the modelling before endorsing the full tunnel option. Models to forecast spills and dissolved oxygen levels played a key role in eliminating alternatives to a full-length tunnel (Figure 8, page 24). They were used to conclude that all alternatives except in-sewer separation would fail the dissolved oxygen standards and to set the 'four spills' criterion itself. The Environment Agency could not provide us with evidence that it had sufficiently understood the impact of uncertainty on the outputs from the models. The Environment Agency's consultants in 2007 reported that the models could predict dissolved oxygen levels which were overly pessimistic when compared to measurements in practice, and made recommendations to refine the modelling in 2009. The Environment Agency partially adopted these recommendations but has not carried out another validation exercise since 2007. The Environment Agency told us that, although it would have been possible to increase confidence in the model results by obtaining more extensive data sets, it did not consider that any of the areas of uncertainty with the results were sufficient to justify the costs necessary to obtain any improved data (paragraphs 2.17 and 2.20).

12 Correcting for inaccurate predictions could have resulted in a smaller, lower cost tunnel. More accurate modelling is unlikely to have affected the choice of a tunnel as the strategic approach, given assessments that alternatives would either fail to meet all key objectives or do so at significantly higher cost. However, it may have resulted in a smaller, lower cost design of the preferred 'Full Tunnel' option. Refinements to Thames Water's sewer model after 2007 indicated that the planned capacity of the Tunnel would considerably outperform the 'four spills' threshold. This allowed Thames Water to reduce the length of the reference design by 9 kilometres in 2009, saving £646 million, while still achieving the 'four spills' threshold. Further refinements to the modelling could have identified the potential for further capacity reductions, albeit through reducing the diameter of the tunnel, which estimates suggest reduces costs relatively less than reducing the tunnel's length. The Department considers that a tunnel of smaller diameter would not have cost significantly less, based on Thames Water estimates from 2006. It considers that a smaller diameter tunnel would have carried a greater risk of non-compliance and fines, and that, following the 2012 ruling, the European Commission would have known it was possible to capture more spills with minor cost increase. The Department considers that the cost of rectifying a tunnel with inadequate capacity would be prohibitive, and that the Tunnel chosen offers greater certainty that the tunnel will be "future-proof" (paragraphs 2.18 and 2.21 to 2.24).

Current project status

13 A specially-created company will construct the Tunnel, and is incentivised to bring the Tunnel into operational use sooner than planned. The Department appraised the costs and benefits of different delivery models (by the public sector, or by Thames Water, or a separate company with contingent government support), before deciding to support a separate infrastructure provider. Bazalgette was appointed in August 2015 to design, build, commission, finance and maintain the Tunnel, following a competition run by Thames Water. Through a separate procurement competition Thames Water started, Bazalgette contracted with three consortia to build the three sections of the Tunnel. In August 2015, the project plan was for the Tunnel to be operational by 2024, though Bazalgette has given contractors incentives to complete construction earlier (paragraphs 1.10, 1.11 and 3.2).

14 Eventual costs to customers are uncertain. Thames Water's customers will ultimately fund this project, with their contributions depending on the final cost. Tunnel costs added £13 on average to Thames Water customers' annual bills in 2016-17 (in 2016-17 prices). Thames Water has forecast that the peak impact of the project on the average annual household bill will range from £20 to £25 (in 2016-17 prices) in the early 2020s. This projection assumes cost overruns are no higher than 30% of the £3.2 billion target price for the project works; although government considers the probability of this occurring to be below 5%. The lower than expected cost of finance has helped to reduce the expected impact of Tunnel costs on household bills from the 2011 prediction of between £70 and £80 a year (paragraphs 3.4, 3.7 and 3.8).

15 Cost estimates have risen over time during planning, but have remained relatively stable since 2011. Between 2006 and 2009, the cost estimate for the preferred Full Tunnel option increased from £2.2 billion to £4.2 billion in 2016 prices (Figure 11), with Ofwat's consultants attributing increases mainly to more realistic cost estimates. Since 2009 estimates have periodically increased (largely due to scope changes aimed at mitigating the risk of failing to achieve planning consents), and decreased (due to Thames Water's modelling refinements after 2007 which allowed the design of a shorter tunnel). The current £4.2 billion estimate consists of £3.2 billion of works Bazalgette will undertake (including £0.5 billion contingency), and Thames Water's enabling works estimated at £1.0 billion. Experience from costs on the Tunnel's 'sister' project, the Lee Tunnel, has been used to improve estimates for the Tunnel. By completing construction early, Bazalgette is aiming to reduce project costs, which could potentially reduce costs for customers (paragraphs 3.5 and 3.6).

16 The Department estimates that the benefits of the Tunnel will exceed the costs, although both are uncertain. Cost-benefit analysis was not critical to the government's endorsement of the Tunnel option, but it provides important information on whether the overall benefits justify the costs. The Department has estimated that the benefits of the project will be between 1.8 and 3.1 times greater than the costs. Estimated benefits are highly sensitive to assumptions used to extrapolate from the surveys, and the ratio has varied considerably during project development. The Department's estimate does not reflect some important but uncertain benefits, such as averted fines payable for non-compliance with the Directive. Approximately 60% of the estimated annual benefits accrue to households outside of Thames Water's service area, although only Thames Water customers will pay towards the Tunnel's costs (paragraphs 3.9, 3.10, and Figures 13 and 14).

Risks and mitigation arrangements to project completion

17 Construction of the Tunnel carries inherent risks due to the project's size, and the number of stakeholders involved. Our previous work on major projects indicates a number of common causes of project failure or cost overruns, including: over-optimistic assumptions; technical challenges not recognised; limited understanding of interdependencies and related projects; short-term financial decisions adding to longer-term costs; and failures in relationships with contractors or in the contractor delivery model. Some Tunnel project arrangements mitigate against these, for example the project can benefit from experience of similarities with the Crossrail and Lee Tunnel construction projects. But some of these risks could materialise during construction, for example knowledge of ground conditions is imperfect, and contractors will need to work well together to deliver to time and minimise costs. Public bodies will need to monitor the project carefully so they can discuss any evidence of risks materialising with those delivering the project at a sufficiently early stage (paragraphs 3.11, 3.13 and 3.14).

18 Government has provided Bazalgette with a contingent financial support package which seeks to mitigate some risks, transferring liability to the taxpayer if those risks materialise. The Department concluded that private delivery of the project would not be financially viable without some form of government support, because of the scale of the project risks and the implications for financing costs that customers would ultimately fund. The Department considers that a call on the support package is highly unlikely, although it estimates that the impact could be very large (£6.6 billion in its 'reasonable worst case' scenario), if several risks materialise. Until the project has been fully commissioned and has completed testing (expected by February 2027), the Department has agreed to:

- either provide an equity injection to Bazalgette if its cost overruns exceed 30% or discontinue and pay compensation;
- lend to Bazalgette if economic or political events make it unable to access debt capital markets as planned;
- indemnify property and liability claims above insurance limits specified in Bazalgette's existing insurance cover, or where insurance is unavailable;
- provide compensation to investors in the event that the project is discontinued; and
- make an offer to purchase Bazalgette or provide compensation to investors if it goes into special administration and remains there for 18 months (paragraphs 3.8 and 3.15 to 3.17).

19 Arrangements have been established aimed at risk mitigation and early identification of potential calls on the support package. Contractual arrangements for costs and payments (including ‘pain and gain-sharing’) provide Bazalgette and its contractors with financial incentives to deliver on time, or before, and manage the risks of cost overruns. Independent assessors will provide quarterly reviews on Bazalgette’s reported progress and project costs. These assessments fulfil a dual role, enabling Ofwat to identify and disallow expenditure which has not been agreed, and providing advance warning of a call on the support package so the Department can make appropriate preparations. The Department’s arrangements should provide it with evidence of any risks materialising and sufficient means to intervene where necessary, and we will consider the operational effectiveness of these arrangements in future reviews (paragraphs 3.19 to 3.23).

20 Despite construction work starting and the prospect of the UK leaving the European Union, the European Commission could yet seek fines against the UK for a continuing breach of the Directive. The timescale in which it would do so is uncertain, and the Commission told us it has not yet made a decision (paragraph 3.24). We have not audited or considered the effects on this project of leaving the European Union.

Part One

Background

1.1 In June 2014, we published a report on the Thames Tideway Tunnel project.² Our report outlined six areas that we considered most critical to achieving value for money for customers and the taxpayer, and criteria that we would use if we were to undertake a value-for-money study in future (**Figure 1**). We did not evaluate the value for money of the project at that point, to avoid influencing the outcome of ongoing competitions for the construction and financing of the Tunnel.

Figure 1
Areas we identified in our 2014 report

Setting clear project objectives	Are the aims of the project clear, measurable and achievable? Is there a clear definition of success?
Appraising the options	Has the preferred option been shown to be the most cost-effective way of meeting the project objectives compared with the alternatives?
Choosing the right delivery model	Does the choice of delivery model maximise value for money in procuring the project?
Managing taxpayer risk	Will a government contingent financial support package help secure private finance at a good price without undermining investors' incentives to deliver a successful project?
Managing project costs and risks	Are costs and risks well understood and do all parties have incentives to keep these as low as possible? Where the interests of private parties are not aligned with those of taxpayers or consumers, is there effective independent scrutiny and challenge of costs?
Setting the right charge for consumers	Is the amount consumers will pay subject to appropriate scrutiny to protect consumers' interests?

Source: National Audit Office, *Thames Tideway Tunnel: early review of potential risks to value for money*, 2014

² Comptroller and Auditor General, *Thames Tideway Tunnel: early review of potential risks to value for money*, Session 2014-15, HC 168, National Audit Office, June 2014.

1.2 Large parts of London’s sewers combine the collection and transfer of sewage and rainwater in the same pipes. By design, these combined sewers discharge into the River Thames via 57 Combined Sewer Overflows (CSOs) when sewers reach their holding capacity, rather than overflowing into, and flooding, London’s built-up areas. Public concern about the impact of these discharges on the environment has grown as their frequency has increased over time, notably after discharges killed large numbers of fish in 2004 and 2011.

1.3 **Figure 2** sets out the timeline of events in developing a solution to the problem of CSO discharges. In 1991, the European Union adopted the Urban Waste Water Treatment Directive (the Directive). The Directive aims to protect the environment from wastewater discharges, with the expectation that large conurbations in member states would comply by 2000. In 2000, Thames Water funded a study aimed at finding a solution to this issue in London, which reported in 2005. In part based on the findings of this study, the European Commission issued a ‘reasoned opinion’ in 2006 stating that the UK was failing to comply with the Directive. The Department for Environment, Food & Rural Affairs (the Department) announced support for the Tunnel as the preferred option in 2007.

1.4 In 2012, the Court of Justice of the European Union found the UK in breach of the Directive due to the frequency of spills. We estimate that the UK could therefore face the possibility of a lump sum fine of between £9 million and £177 million, and recurring daily fines amounting to between £11 million and £227 million per year (in 2016 prices), until compliance is verified by the Commission.³ A package of measures designed to improve water quality in the Tideway concluded in January 2016 with the completion of the Lee Tunnel, but Thames Water estimates that spills will by 2021 still reach 59 for the highest-spilling CSO in a ‘typical year’, with discharge volumes at 18 million cubic metres.⁴

1.5 The Department has overall policy responsibility for water and sewerage in England, overseeing compliance with European Union environmental directives, and is the lead government department for the project. Other public bodies have responsibilities in relation to the problem and action to find a solution:

- The Environment Agency is the environmental regulator in England. It is responsible for requiring Thames Water to identify and implement solutions to limit pollution.
- The Water Services Regulation Authority (Ofwat) is the economic regulator of the water industry in England and Wales. Ofwat has duties to protect the interests of consumers, and to ensure that efficient companies can finance their functions. In doing so, Ofwat must also promote economy and efficiency by water companies.
- Other public bodies have been involved during development of the project, including HM Treasury, and the Infrastructure and Projects Authority.

³ These ranges are based on our application of the European Commission’s advisory formula for calculating non-compliance fines. The level of fines is ultimately a matter for the Court.

⁴ Thames Water, *Needs Report*, 2010.

Figure 2

Development timeline for the Thames Tideway Tunnel

1991	May	European Urban Waste Water Treatment Directive signed into law.
2000	December	Deadline for London's compliance with the Directive.
2005	February	Thames Tideway Strategic Study issued its final report recommending a full-length tunnel.
2005	March	European Commission first wrote to the Department citing complaints received around high level of spills in the Tideway.
2006	February	Ofwat-commissioned Jacobs Babbie report published, suggesting a shorter, two-tunnel alternative solution to the Tunnel.
2006	April	European Commission issued a Reasoned Opinion against the UK government for failing to comply with the Directive.
2006	December	Thames Water published analysis considering 'Full Tunnel' and 'East-West Tunnel' solutions, concluding that the latter would fail required environmental standards.
2007	March	The Department announced that a full-length tunnel was the preferred option.
2010	July	European Commission lodged a court application against the UK for breach of the Directive.
2010	September	Thames Water <i>Needs Report</i> published, concluding that the Tunnel is the most cost-effective way of securing environmental objectives.
2012	March	National Policy Statement for Waste Water was presented to, and approved by, Parliament, setting out government's view that the national need for the Tunnel had been demonstrated, and that a tunnel-based solution was the only viable option.
2012	October	Court of Justice of the European Union found the UK in breach of the Directive for London, due to unacceptably high spill frequency along the Tideway.
2013	October	Thames Water announced shortlists of consortia bidding for the three main construction work packages.
2014	September	Ministers granted Development Consent for the Tunnel.
2015	August	Ofwat granted Bazalgette Tunnel Limited a regulatory licence; Government Support Package agreed; project achieved financial close.
2016	January	Bazalgette began pre-construction work at various sites.
2018	May	Tunnelling to begin.
2021	August	Tunnelling to be completed.
2022	October	System commissioning to begin.
2024	March	Tunnel expected to be fully operational (subject to testing).
2027	February	Commissioning and systems acceptance completed, triggering expiry of the government's contingent support package.

Source: National Audit Office analysis of documents provided by the Department

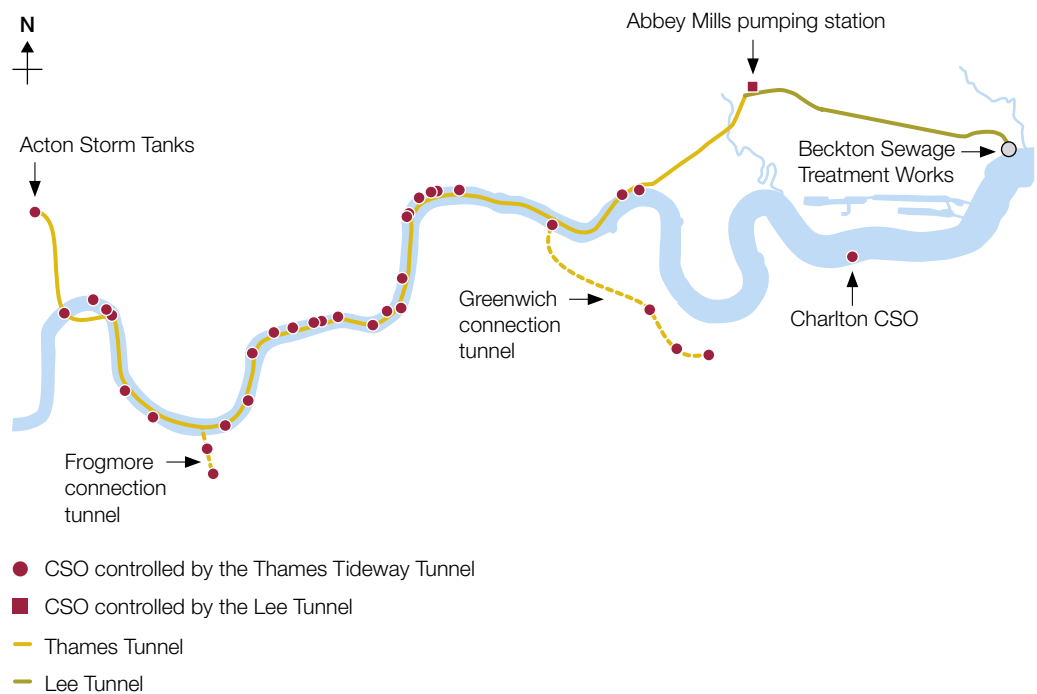
1.6 Thames Water, a privately-owned company, is responsible for sewerage infrastructure in London, and for developing a solution to the overflows problem. As the licensed sewerage undertaker for London, Thames Water has duties to ensure that its sewerage system meets the Directive requirements. The government is involved owing to the scale of the issue and because it would be liable for fines for Directive breaches.

1.7 Government developed strategic objectives for a solution: to secure compliance with the Directive, and to improve the environmental quality of the Tideway by reducing sewage overflows. In 2014, the government added a third objective, to ensure sufficient strategic sewer capacity to accommodate London’s growth for at least the next hundred years.

1.8 The Thames Tideway Tunnel has been identified as the government’s preferred option to address the environmental impact of residual storm sewage overflows into the Tideway and meeting its objectives. The planned Tunnel project will build a large sewer running under the River Thames for 25 kilometres from Acton in West London to Abbey Mills in East London (**Figure 3**).

Figure 3
Planned route of the Thames Tideway Tunnel

The Tunnel will actively manage flows from 34 Combined Sewer Overflows (CSOs)



Note

1 Charlton CSO is to be controlled by operation changes at Greenwich pumping station and improvements at Crossness sewage treatment works.

1.9 While the project will be delivered and financed privately, the government has provided a contingent financial support package (the GSP) to enable this. Thames Water undertook planning, design of tenders and overall system design. A separate infrastructure provider will deliver the project, overseeing the work of three consortia which will each undertake detailed design, and construction of, separate sections of the Tunnel. Thames Water's customers are expected to meet the project's costs through their water bills.

1.10 Since our 2014 report:

- a specially-created private company, Bazalgette Tunnel Limited (Bazalgette) has won Thames Water's infrastructure provider procurement competition, to build, finance, own and operate the Tunnel. Thames Water also awarded three tunnelling works contracts following procurement competitions;⁵
- a regulatory framework has been established covering Bazalgette. Ofwat issued Bazalgette with a project licence in August 2015;
- government has provided a contingent financial support package to Bazalgette;
- the project has received development consent; and
- Bazalgette began preparations for construction work in 2016.

1.11 Thames Water and the Department considered the merits of three alternative models for delivering the project, alternatively by: Thames Water; an independent 'Infrastructure Provider'; and the public sector. The Department's financial consultants (Ernst & Young) appraised the costs and benefits of these delivery models, concluding that a separate Infrastructure Provider was the most cost-effective way of delivering the Tunnel while satisfying policy preference to minimise calls on government capital, and limiting customer bills.

1.12 The Thames Tideway Tunnel has attracted opposition from a range of local authorities and individuals who have variously considered that:

- environmental performance thresholds set for the Tideway go beyond the requirements of the Directive;
- government has not properly considered whether a mix of solutions could achieve environmental objectives more cheaply;
- the cost-benefit analysis for the Tunnel is flawed; and
- the Tunnel is no longer needed owing to upgrades to the London sewerage system since the Tunnel was first proposed, or due to the prospect that the UK will leave the European Union.

⁵ A contract has also been awarded to a 'Systems Integrator', which will be responsible for installing, testing and maintaining communications and monitoring equipment.

1.13 In this report we update developments since June 2014, including programme progress and estimates of costs. We examine how the Department and the Environment Agency have managed risks in areas which are now substantively complete, particularly in setting objectives and appraising options. We also look at the risks to customers and the taxpayer which the public sector need to manage to protect value-for-money during the construction phase. It is too early to form a value-for-money conclusion on the whole project but this report, together with our 2014 report, outlines what we would expect to see when the project is complete.

1.14 The methods of this report are detailed in Appendix One.

Part Two

Setting objectives and appraising options

2.1 This part considers how the Department's objectives were translated into criteria used to compare options, and how it appraised alternative solutions.

2.2 The Urban Waste Water Treatment Directive (the Directive) generally requires member states to collect and treat all waste water in normal climatic conditions. Recognising that unusual weather may render this unfeasible, the Directive requires member states to decide on measures to limit pollution, such as an acceptable number of overflows in a year. The Directive does not set thresholds that define compliance for Combined Sewer Overflows (CSOs).

Developing objectives and standards

Process

2.3 In 2000, Thames Water set up the independently-chaired Thames Tideway Strategic Study to identify the environmental harm that storm sewage overflows cause, and to identify options to address them. In the case of the Tideway, the Study concluded that existing measures failed to adequately limit the impact of overflows, and that existing guidance was not well placed to deal with discharges on the scale of a catchment the size of London's. The study reported three areas of harm:

- **Aesthetic:** sewage-derived solids creating offensive conditions both on the river and the foreshore.
- **Ecological:** reduced oxygen levels in water following discharges, resulting in fish mortality or undesired behaviour (eg avoiding certain stretches).
- **Health:** increased levels of pathogenic microbes in water following discharges, posing a higher health risk to river users.

2.4 The Study proposed criteria to measure satisfactory performance against their three areas of harm and to identify appropriately protective solutions:

- **Dissolved oxygen standards.** Sewage discharges reduce dissolved oxygen levels, causing harm to fish. Four duration-based dissolved oxygen thresholds were set. These allow dissolved oxygen below a certain threshold for a given 3 kilometre stretch of river, for a defined number of tides; with progressively fewer tides allowed for lower thresholds.
- **Flow-based criteria to identify unsatisfactory CSOs.** In 2005, the Environment Agency set thresholds for each of the three areas of harm which defined CSOs as unsatisfactory based on their average discharge volume, loading, and the sensitivity of the surrounding area (**Figure 4**). Failure of any one threshold resulted in unsatisfactory status. Solutions were required to limit pollution from all unsatisfactory CSOs, but criteria defining acceptable limits were not devised.
- **The ‘four spills’ criterion** – A third criterion was also established to use in place of the first two, in order to reduce modelling effort. Thames Water and the Environment Agency agreed that a maximum of four spill events in a modelled ‘typical year’⁶ would deliver satisfactory environmental performance.

Figure 4
Environment Agency methodology for categorising unsatisfactory Combined Sewer Overflows (CSOs)

Objective	Criterion for ‘unsatisfactory’ status	Inputs
Aesthetic	Average discharge above a threshold giving rise to aesthetic harm, with lower thresholds set for areas of greater public access and activity. Historical complaints received about a CSO were also sufficient to warrant unsatisfactory status.	Sewer model flow predictions from 21 rainfall events. Complaints records. Environment Agency assessment of high visibility, or heavily-frequented areas of the Tideway.
Ecological	CSOs whose average polluting load during storms is above a threshold likely to cause dissolved oxygen deficits which harm the Tideway ecology.	Sewer model flow predictions from 21 rainfall events. Dissolved oxygen standards. Environment Agency assessment of sensitivity of three sections of the Tideway.
Health	Average discharge above a threshold giving rise to unacceptably high health risks to recreational users with lower thresholds applying to areas of heavier recreational use.	Sewer model flow predictions from 21 rainfall events. Environment Agency assessment of heavily-used areas of the Tideway.

Source: Environment Agency, *An Assessment of the Frequency of Operation and Environmental Impact of the Tideway CSOs*, (2005)

6 The rainfall data used to represent the ‘typical year’ is from 1979-80, a year chosen by modelling consultants WRc as being the most representative of a 34-year historical rainfall series.

The Department accepted these three measures as a valid basis for appraising potential solutions.

Assessment

2.5 In our 2014 report (Figure 1) we outlined an expectation that the Environment Agency would set evidence-based standards, and apply due diligence where it relied on others' work. We also expected the Department to understand how the European Commission interprets compliance with the Directive. We did not evaluate against these criteria in our 2014 report as competitions for the construction and financing of the Tunnel were still ongoing.

2.6 The Department met with the European Commission in 2007 and secured informal agreement that the four spills criterion would be compliant. The Commission nonetheless initiated court proceedings against the UK in 2010 as the Department's 2008 forecast was that the Tunnel would be complete by June 2020, but compliance had been required by the end of 2000.

2.7 Laboratory experiments measuring the impact on fish of reduced oxygen levels underpinned the dissolved oxygen standards. Research showed that dissolved oxygen levels below 4 milligrams per litre were associated with avoidant behaviour in some fish, and levels below 3 milligrams per litre were associated with increased mortality risk.⁷ The Environment Agency's judgement was used to set thresholds for the 'Health' and 'Aesthetic' criteria.

2.8 The dissolved oxygen standards underwent independent peer review in 2003, which found the methodology scientifically robust. A working group of Environment Agency staff and external experts reviewed and upheld the thresholds in 2012. The dissolved oxygen standards are comparable to standards contained in other UK guidance to manage dissolved oxygen levels in UK waterways. The thresholds for identifying unsatisfactory CSOs were primarily based on Environment Agency judgement and were only reviewed internally (and upheld) in 2011.

2.9 The Environment Agency will require Thames Water to monitor the duration of discharges at all CSOs connected to the Tunnel, allowing annual spill frequency to be counted. The Environment Agency can also monitor compliance against the dissolved oxygen standards through its 8 monitors stationed across the Tideway. It has no plans to monitor performance against the Health or Aesthetic criteria.

⁷ Thames Water, *Needs Report: Appendix F*, 2010, p. 11.

Outcomes

2.10 Our analysis of Thames Water’s 2016 CSO discharge data shows that several CSOs continue to spill all year round, suggesting a risk that London remains non-compliant with the Directive (**Figure 5**). Comparison of this data with dissolved oxygen measurements, however, suggests that achieving the four spills criterion is not essential for maintaining satisfactory dissolved oxygen conditions in the river. Hammersmith was identified in 2005 as being a large-volume, frequently spilling CSO with significant adverse effect on dissolved oxygen levels.⁸ For the last April to September period in which the Tideway has historically been at its most vulnerable to dissolved oxygen deficits, we estimate that Hammersmith spilled eight times, discharging 1.8 million cubic metres of waste water. Environment Agency data on dissolved oxygen showed no breaches of any dissolved oxygen threshold in the area during this period. The Department considers that inferences should not be made from a single year of data.

2.11 Three other European Union member states operate thresholds as high as 10 spills per CSO per year (**Figure 6** on page 22). This may provide some assurance that if the threshold is met the Tunnel will be deemed compliant with the Directive. The Department considers thresholds adopted by other member states to demonstrate compliance are not relevant comparators, because of differences in the nature of overflows and water areas affected. The Department also considers that the ‘four spills’ level of protection reflects the Government’s aim to achieve its environmental and legal objectives well into the future, having regard for the likely impacts of population growth and climate change.

Options appraisal

Process

2.12 The Department’s preferred option from 2007 was a full tunnel, involving a storage tunnel intercepting CSOs from West to East London and transferring waste water to Beckton sewage works. It was developed alongside a range of other potential solutions to overflows, in three separate exercises over the period 2000–2010:

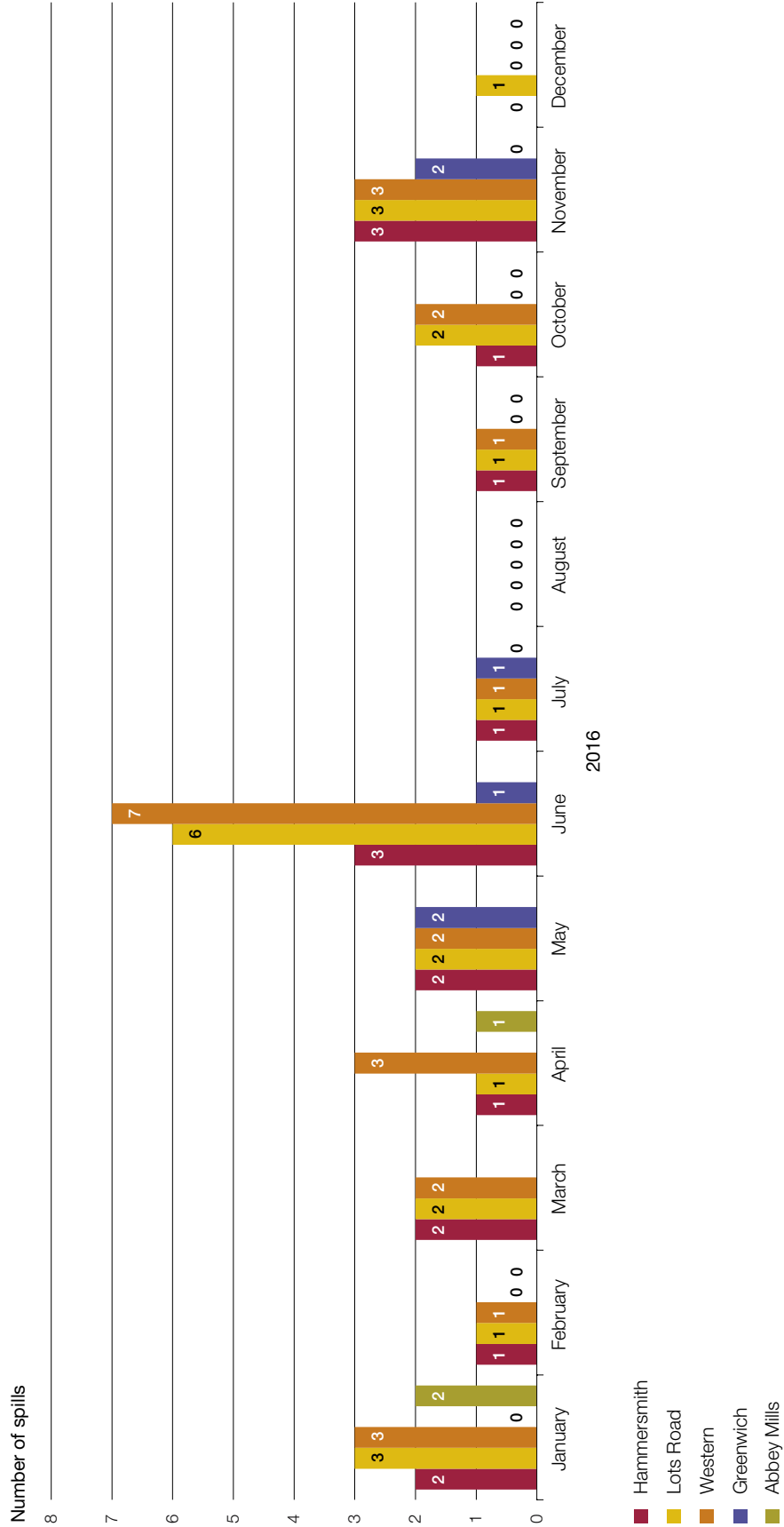
- **The Thames Tideway Strategic Study (2000–2005):**⁹ considered options based on location (before waste water reached sewers, in the sewers, at the CSOs, and in the river), and then conducted feasibility, modelling and cost-benefit studies on eight sub-options to address spills at CSOs.
- **The Thames Tideway Advisory Group (2005-06):** considered three variants of a full tunnel option, against three variants for a two-tunnel solution involving tunnels west and east of London. The option appraisal considered dissolved oxygen compliance, spill frequency and benefits and costs.
- **The Needs Report (2009-10):** considered three routes for a full tunnel option and two alternative approaches: Sustainable Urban Drainage Systems, and In-Sewer Separation. The option appraisal considered dissolved oxygen compliance for different tunnel configurations, but only spill frequency and cost for the alternatives.

⁸ Environment Agency, *An Assessment of the Frequency of Operation and Environmental Impact of CSOs*, 2005, p. 9.

⁹ The Steering Group consisted of Thames Water who funded the Study, the Department, the Environment Agency, the Greater London Authority; and the Water Services Regulation Authority (Ofwat) which maintained observer status.

Figure 5
 Estimated spills at monitored Combined Sewer Overflows in 2016

Combined Sewer Overflows along the Tideway continue to discharge all year round



- Notes**
- 1 Spill counting follows the Thames Water methodology of counting all discharges not separated by a 24 hour dry period as a single spill.
 - 2 Figures are estimates due to the role of human input in recording discharge duration and volumes.

Source: National Audit Office analysis of Thames Water data

Figure 6

Comparison of the project's target spill criterion against other guidance

Water body	Maximum allowed number of spills per CSO
UK Shellfish waters	10 per year
UK Bathing waters	3 per bathing season
Thames Tideway	4 per 'typical year' ¹
Belgium (vulnerable water bodies)	7 per year
Belgium (non-vulnerable water bodies)	10 per year
Netherlands (coastal and transitional waters)	10 per year on average
Poland (leisure/public areas)	10 per year
Ireland (recreational waters)	6 per year

Note

1 Assessed over a 41 year rainfall series (1970 to 2010), the Tunnel solution was forecast by Thames Water to result in between 1 and 7 spill events in a year, depending on the year.

Source: Milieu, *Assessment of Impact of storm water overflows from combined waste water collecting systems on water bodies in the 28 EU Member States*, January 2016; DETR, *Working Document for Dischargers and Regulators*, July 1997, updated April 2009

Assessment

2.13 In our 2014 report (Figure 1) we said we would expect the Department and the Environment Agency (and where appropriate Ofwat) to have:

- ensured clear links between objectives and appraisal criteria;
- ensured a comprehensive appraisal of a broad range of options;
- established a robust evidence base to understand the effectiveness, costs and benefits of proposed solutions, reflecting the most up-to-date information, and including sensitivity analysis to test the feasibility and forecast environmental impact of options; and
- subjected all appraisal work to quality assurance to check for errors and scrutinise the underlying assumptions in models.

2.14 For approval, solutions needed to achieve the dissolved oxygen standards based on estimated population growth and climate change to 2021. To simplify compliance testing of alternatives to the Full Tunnel solution, Thames Water and the Environment Agency agreed that a four spills annual threshold in a modelled 'typical year' would meet the environment standards and comply with the Directive.

2.15 We found a wide range of solutions were considered, although combinations of alternative technologies were not appraised after the Department endorsed a full-length tunnel as the preferred option in 2007. In part, this decision was based on a desire to limit the risk of European fines. The Department reviewed its position and concluded in 2014 that, given the 2012 Court of Justice ruling, pausing the Tunnel to consider alternatives further would likely increase the risk of fines for breaching the Directive.

2.16 The Department assessed the Full Tunnel option as the lowest-cost option that would achieve its objectives by 2020. The Department considered that alternatives either did not achieve the dissolved oxygen standards, led to too-frequent spills, or would only achieve equivalent performance to the Tunnel at far greater cost (**Figure 7**).

Figure 7

Thames Tideway: Solutions appraised 2000–2010

Option appraisals reporting in 2005, 2006, and 2010 indicated that alternatives to the Full Tunnel either failed the dissolved oxygen standards or cost more than the Tunnel

	Compliance with dissolved oxygen standard	Spills events in the 'typical year' for highest spilling CSO	Delivery timescale relative to 2015	Cost, 2016 prices (£bn)
Baseline: Lee Tunnel and treatment plant upgrades (2010)	Fail	59	not assessed	not costed
Sustainable Urban Drainage Systems (2010)	Fail ²	>10	25+ years	11.2–24.0
In-Sewer Separation (2010)	Pass ²	4	25+ years	12.1–25.8
Two Tunnel/East-West Solution (2006)	Fail	9 ³	5 years	2.4–2.5
Full Tunnel Option (2010)	Pass	4	6 years	4.2
Transfer to high capacity treatment plant (2005)	Fail	not assessed	not assessed	1.2–2.6
Multiple screened outlets (2005)	Fail	not assessed	not assessed	1.4–4.1
Multiple screened outlets and storage (2005)	Fail	not assessed	not assessed	1.9–5.0
Storage shafts by riverside (2005)	Fail	not assessed	not assessed	1.5–3.5
Screening at individual CSOs (2005)	Fail	not assessed	not assessed	11.7
Displacement to wetlands (2005)	Fail	not assessed	not assessed	2.7
In river: Bubblers and skimmers (2005)	Not assessed	as baseline	not assessed	not costed

Notes

- 1 Where options were assessed multiple times, figures refer to the most recent exercise.
- 2 Conformity with the dissolved oxygen standard was not explicitly modelled for these options, but assessed using the four spills criterion.
- 3 On average 9 spills per year was predicted for CSOs intercepted by the Tunnel, but non-intercepted CSOs were assessed to spill as per the baseline.

Source: Thames Tideway Strategic Study, *Solutions Working Group Report* 2005, Thames Water, *Tackling London's Sewer Overflows*, 2006, Thames Water, *Needs Report*, 2010

2.17 Modelling was a key element of the decision-making process (**Figure 8**).

For alternative solutions this estimated:

- **CSO average spill volumes.** The Sewer Model estimated average spill volumes by CSO for 21 rainfall events, which were then used to assess whether they were unsatisfactory, according to the Environment Agency's thresholds for defining harm.
- **Spills in a typical year.** The Sewer Model used rainfall data from a 'typical year' (1979-80) to estimate the number of spills which would result with a solution in place.
- **Whether the dissolved oxygen standards would be met.** The water quality (Estuary) model used a historical rainfall data series to predict the number of breaches of the four dissolved oxygen thresholds which would have resulted over 34 years with a solution in place, permitting this to be compared with allowed number of breaches over this period.

2.18 Reviewers have found that Thames Water's sewer model broadly follows good practice. It has been refined since 2007, enabling the Tunnel's final design to be 9 kilometres shorter, reducing estimated costs by £646 million. Despite improvements in the model's predictive ability, Thames Water told us it did not revisit previously appraised solutions as the Secretary of State had already written to Thames Water in 2007 asking it to proceed with a full-length tunnel.

2.19 Ofwat has, through its consultant Mott Macdonald, scrutinised Thames Water's Tunnel costings since 2007. Challenges have led to revisions in costings as the project has progressed. Mott MacDonald is involved elsewhere in the project, performing design work for the consortia of contractors undertaking the Tunnel's East section. Ofwat has put in place a mechanism to prevent conflicts of interest, which we have not audited as part of this review. There was no independent scrutiny of costings for alternative options to the Tunnel.

2.20 The Environment Agency used outputs from the modelling to test the compliance of options with its success criteria (paragraph 2.4). We found that the Environment Agency relied principally on Thames Water and Thames's consultants to gain assurance over the models, and that it could not provide evidence that it had sufficiently understood the impact of uncertainty over modelling inputs to two key areas of the option appraisal:

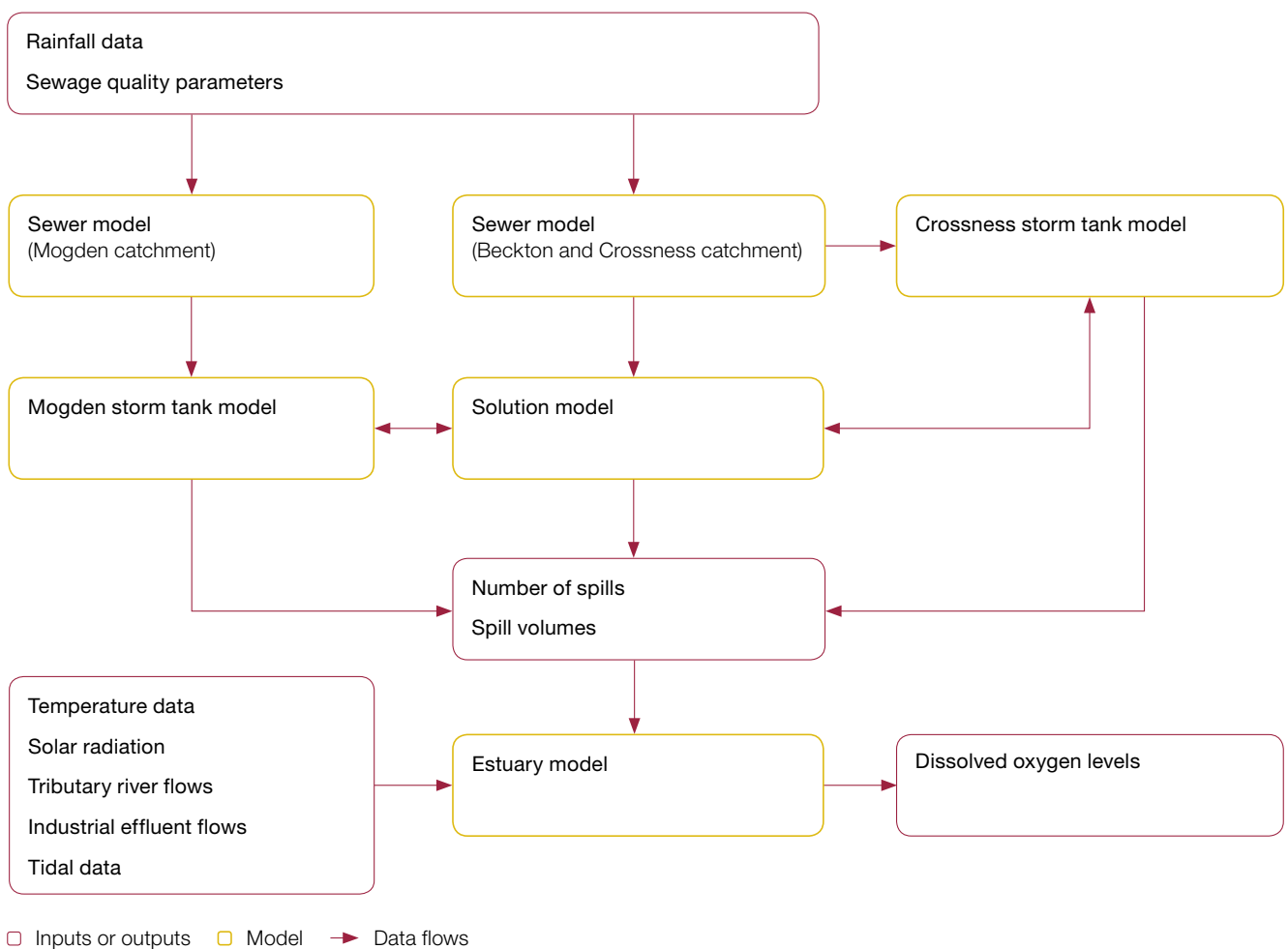
- **Categorisation of unsatisfactory CSOs.** In identifying unsatisfactory CSOs, the Environment Agency relied on Thames Water data from 21 rainfall events, but could not explain to us how these events had been chosen or why they were representative of usual weather conditions.

- **Compliance testing of options against the dissolved oxygen standards.**

In 2007, the Environment Agency's consultants (WRc) reported that the water quality (Estuary) model could predict dissolved oxygen levels which were overly pessimistic when compared to measurements in practice.¹⁰ WRc's subsequent review (in 2009) again noted that the model's dissolved oxygen predictions could be conservative, and suggested eight areas for improvement. The Environment Agency partially adopted these recommendations, but has not carried out another validation exercise since 2007. The Environment Agency told us that, although it would have been possible to increase confidence in the model results by obtaining more extensive data sets, it did not consider that any of the areas of uncertainty with the results were sufficient to justify the costs necessary to obtain any improved data.

Figure 8

Simplified representation of the Tideway modelling framework



Source: National Audit Office analysis of Thames Water modelling documentation

¹⁰ Two out of six simulated storm events predicted fails of the dissolved oxygen standards but monitoring station data suggested levels were compliant.

Outcomes

2.21 Given the criteria used to appraise options, the risk that modelling uncertainty influenced the choice of technological solution is likely to have been small. Only one alternative comparable in cost and delivery timetable to the Full Tunnel (the East-West Tunnel) came close to achieving the dissolved oxygen standards. As this solution would fail to limit pollution from approximately half of ‘unsatisfactory’ CSOs (**Figure 9**), it would have been eliminated irrespective of a compliant dissolved oxygen result which a more accurate Estuary model could have yielded. Our analysis indicates that CSO categorisation was not sensitive to inputs provided by the Sewer model: average flows would have to have been half their estimated level to cause any unsatisfactory CSOs to lose this status.

2.22 The Tunnel’s storage capacity was designed to meet the requirement to accommodate volumes of wastewater resulting from all but the four largest spill events in the ‘typical year’ within the Thames Tideway Tunnel and the Lee Tunnel. The Environment Agency agreed this level of performance to achieve environmental objectives and compliance with the Directive, having regard for the future effects of population growth and climate change.

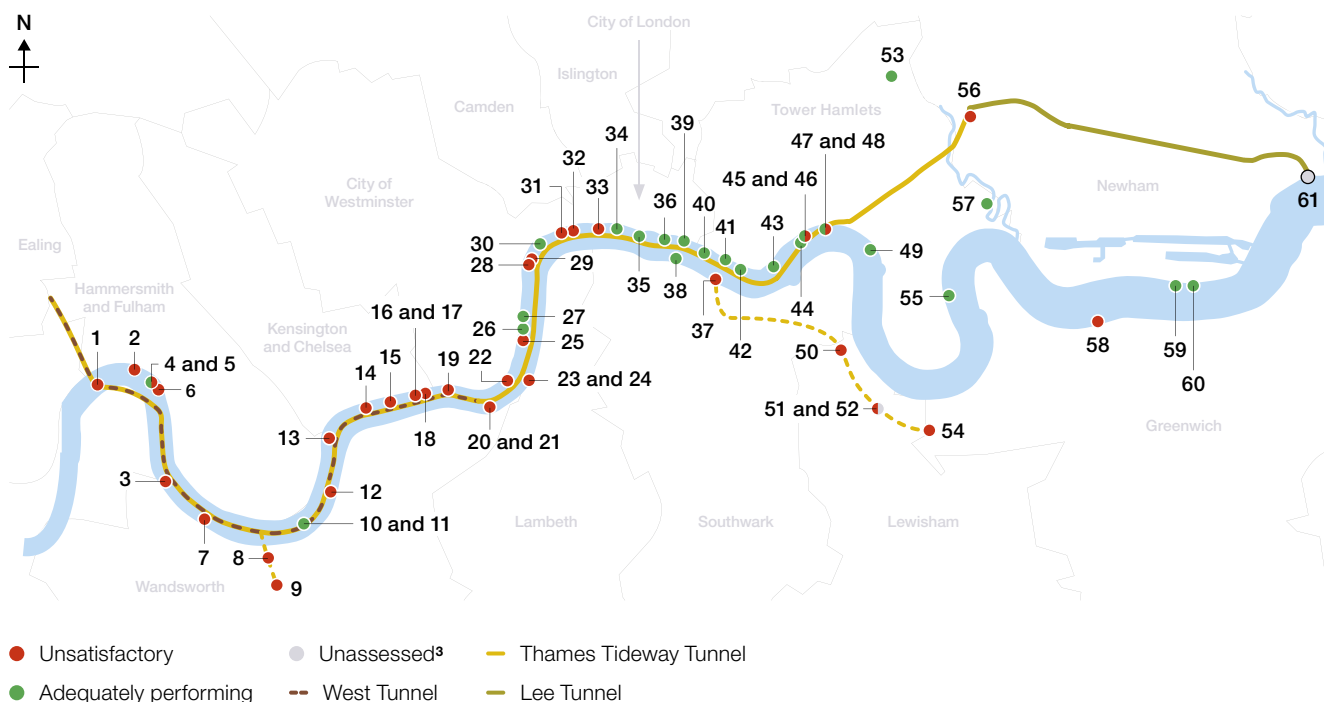
2.23 More accurate modelling could have resulted in a smaller, lower cost design of the preferred ‘Full Tunnel’ option. Refinements to Thames Water’s sewer model after 2007 indicated that the planned capacity of the Tunnel would considerably outperform the ‘four spills’ threshold, allowing Thames Water to reduce the length of the reference design by 9 kilometres in 2009 (paragraph 2.18). Our review of modelling found that the sewer model could over-predict spill volumes, which could mean that a smaller diameter tunnel would limit pollution from all unsatisfactory CSOs while still meeting the four spills threshold. For a given capacity reduction, the Department’s estimates suggest that this approach would reduce costs by less than was achieved through reducing the Tunnel’s length. Further refinements could have reduced uncertainty about modelling and increased confidence that the Tunnel was the appropriate size, and cost, for delivering the project objectives.

2.24 The Department considers that a tunnel of smaller diameter would not have cost significantly less, based on Thames Water estimates from 2006. It considers that a smaller diameter tunnel would have carried a greater risk of non-compliance and fines, and that, following the 2012 ruling, the European Commission would have known it was possible to capture more spills with minor cost increase. The Department considers that the cost of rectifying a tunnel with inadequate capacity would be prohibitive, and that the Tunnel chosen offers greater certainty that the solution will be “future-proof”.

Figure 9

Unsatisfactory CSOs and the routes of the Full Tunnel and East-West Tunnel¹ solutions

The East-West Tunnel would not have limited pollution in approximately half of the CSOs identified as ‘unsatisfactory’ by the Environment Agency along the Tideway



Number and name of Combined Sewer Overflow

1 ● Acton	17 ● Smith St. (storm relief)	33 ● Fleet	49 ● Blackwall Sewer
2 ● Stamford Brook	18 ● Ranelagh	34 ● Pauls Pier	50 ● Earl
3 ● West Putney	19 ● Western	35 ● Goswell St.	51 ● Deptford
4 ● Brook Green	20 ● South West	36 ● London Bridge	52 ● Deptford Creek ³
5 ● North West Relief	21 ● Heathwall	37 ● Shad Thames	53 ● Wick Lane ²
6 ● Hammersmith	22 ● Kings Scholar Pond	38 ● Battle Bridge	54 ● Greenwich
7 ● Putney Bridge	23 ● Clapham	39 ● Beer Lane	55 ● Isle of Dogs
8 ● Frogmore (Bell Lane)	24 ● Brixton	40 ● Iron Gate	56 ● Abbey Mills
9 ● Frogmore (Buckhold Rd.)	25 ● Grosvenor	41 ● Nightingale	57 ● Canning Town
10 ● Jews Row (Wandle Valley) ²	26 ● Horseferry	42 ● Union Wharf	58 ● Charlton
11 ● Jews Row (Falcon Brook) ²	27 ● Wood St.	43 ● Wapping Dock	59 ● Henley Rd.
12 ● Falcon Brook	28 ● Regent St.	44 ● Cole Stairs	60 ● Store Rd.
13 ● Lots Rd.	29 ● Northumberland St.	45 ● Bell Wharf	61 ● Tideway CSO ³
14 ● Church St.	30 ● Savoy St. ²	46 ● North East Relief	
15 ● Queen St.	31 ● Norfolk St.	47 ● Ratcliffe	
16 ● Smith St. (main line)	32 ● Essex St.	48 ● Holloway	

Notes

- 1 The East-West Tunnel solution refers to the West Tunnel and the Lee Tunnel.
- 2 Local modifications in place since original classification mean that these CSOs are deemed to be satisfactorily controlled.
- 3 These CSOs have not been assessed using the Environment Agency's flow-based criteria.

Part Three

Project status, risks and mitigations

3.1 This part outlines: what the Thames Tideway Tunnel project is expected to deliver; the estimated costs and benefits; the project risks and their mitigation; and the potential costs to Thames Water customers and the taxpayer.

Delivering the project

3.2 Bazalgette Tunnel Limited (Bazalgette) was appointed in August 2015 to design, finance, build, commission, own and maintain the Tunnel, following a procurement competition run by Thames Water. Following a separate tendering process started by Thames Water, Bazalgette contracted with three consortia to build the three sections of the Tunnel (West, Central and East). Thames Water will design, build and commission enabling works to facilitate the connection of the Tunnel to its sewer network.¹¹ The project plan at licence award was for the Tunnel to be fully operational by 2024 (**Figure 10**), but Bazalgette has incentivised contractors to complete construction up to two years earlier.

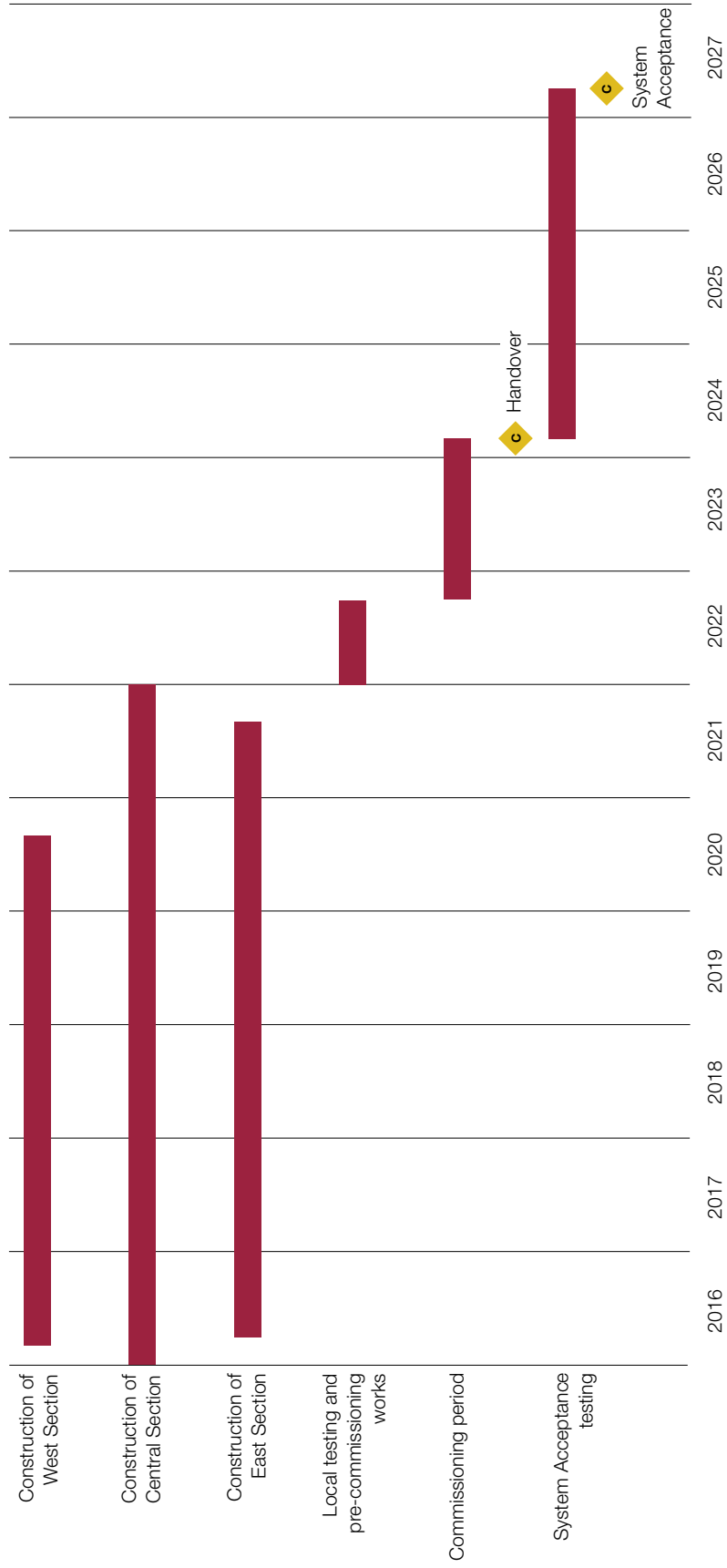
3.3 The Department has set out its role during the construction phase as:

- together with Ofwat, holding Bazalgette to account for delivery of the project to time, cost and quality;
- monitoring any developments which could increase the risk of a call on the Government Support Package (GSP) (paragraphs 3.15 to 3.17);
- monitoring any changes to the project in terms of design or its financing; and
- taking suitable and early action in the event that one of the elements of the GSP is, or is likely to be, triggered.

¹¹ Enabling works includes project development work, procurements and works necessary to hand over sites to Bazalgette.

Figure 10
The delivery timetable for the Thames Tideway Tunnel

The Tunnel is expected to be fully operational by March 2024



Notes

- 1 Commissioning refers to the process of integrating the Tunnel into the wider sewer network by progressively allowing flows into it.
- 2 Thames Water will conduct system acceptance tests to optimise operation and maintenance activities under a range of weather conditions.

Project cost estimates

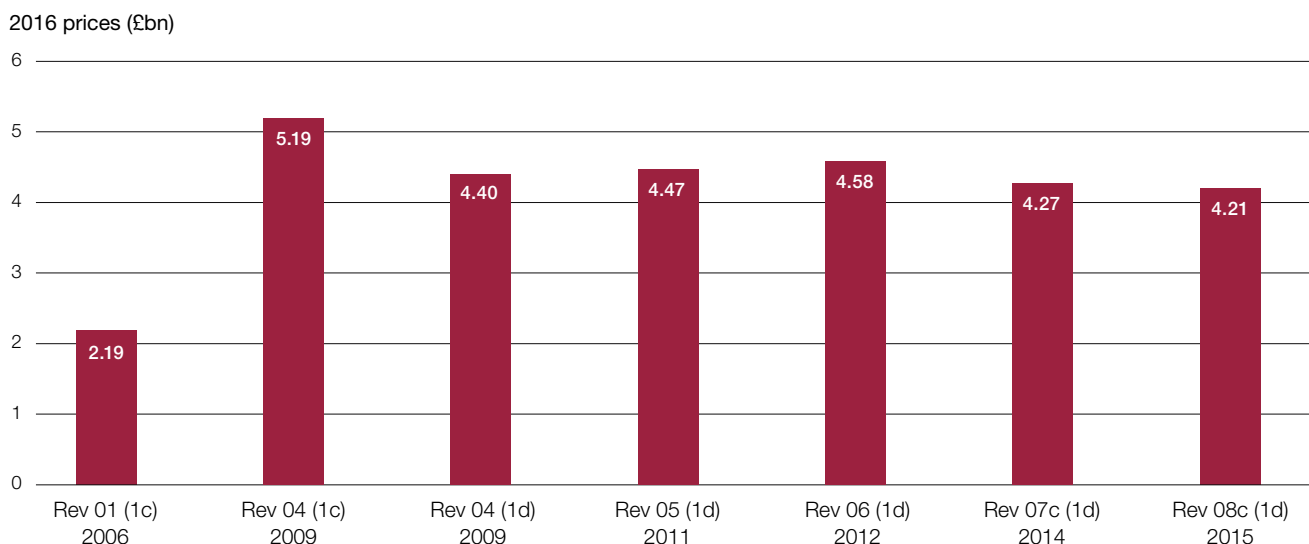
3.4 If costs are in line with current expectations, Thames Water's customers will fund the £4.2 billion capital costs over the project's expected economic life (in 2016 prices), plus ongoing running costs. Thames Water's customers will ultimately pay less or more than this, depending on whether total costs are lower or higher than current expectations.

3.5 Cost estimates have risen over time during planning, but have remained relatively stable since 2009. The initial costing for a full tunnel option in 2006 was £2.2 billion, although the cost of the Tunnel increased significantly to £5.2 billion by 2009 (**Figure 11**). Ofwat's consultants, Mott MacDonald, attributed the increases primarily to more realistic cost estimates for carrying out required works, and a greatly increased level of contingency for risk, which had increased to £1.2 billion. The current £4.2 billion estimate consists of £3.2 billion to be undertaken by Bazalgette (£1.9 billion base construction costs, £0.8 billion indirect costs and £0.5 billion contingency), and Thames Water's enabling works estimated at £1.0 billion. Bazalgette is targeting a saving on this estimate, through completing construction early and therefore reducing headcount and time-related construction costs sooner.

Figure 11

Changes in the estimated cost of the Tunnel over time

The Tunnel's estimated cost has stayed relatively stable since 2009 (2016 prices)



Notes

- Option 1c refers to a longer configuration of the Tunnel which was the previously preferred option.
- Option 1d refers to the shortened 25km tunnel which is the current specification of the Tunnel.

Source: Ofwat analysis of Thames Water costings

3.6 Factors affecting cost estimates' maturity in major projects include improvements in information, scope changes and unexpected developments.¹² Since 2009, estimates of the Tunnel's cost have periodically increased (largely due to scope changes aimed at mitigating the risk of failing to achieve planning consents) and decreased (owing to Thames Water's modelling refinements after 2007 which allowed the design of a shorter tunnel – see paragraph 2.18). Ofwat's consultants have not raised material cause for concern over the current cost estimate. Experience from costs on the Tunnel's 'sister' project, the Lee Tunnel, has been used to improve understanding of costs.

3.7 Thames Water customers are already paying for the project, and will continue to do so over its expected 120-year economic life. Thames Water's modelling indicates that the charge on the average annual household bill will rise from £13 in 2016-17 (in 2016-17 prices) to a peak of between £20 and £25 (in 2016-17 prices), before declining gradually (**Figure 12** overleaf). This projection assumes that cost overruns are no higher than 30% of the £3.2 billion target price for the project works, although the Department considers the probability of this occurring to be below 5%.¹³ Bazalgette will invoice Thames Water on a monthly basis according to a charging formula similar to that used to calculate water bills in England and Wales. Thames Water is obliged under the terms of its regulatory licence to collect the required revenues from its customers and pass these to Bazalgette. Ofwat reviews and approves Tideway charges annually.

3.8 In 2015, the government put in place the GSP, which transfers some potential project risks from customers and investors to taxpayers (paragraphs 3.15 to 3.17). By reducing potential risks to investors, the GSP was key to Bazalgette financing the project on a lower regulated return than would have been possible otherwise (2.497%). Arrangements put in place in 2015 governing how Bazalgette would earn revenues also provided greater certainty around expected costs. To date Bazalgette has arranged £1.27 billion of equity finance and £2.2 billion of debt.¹⁴ The lower than expected cost of finance has helped to reduce the expected impact of Tunnel costs on household bills – in 2011 the Department announced an estimated annual impact on bills at between £70 and £80.¹⁵

¹² Various past reports identify common contributory factors, for example: Comptroller and Auditor General, *Delivering major projects in government: a briefing for the Committee of Public Accounts*, Session 2015-16, HC 713, National Audit Office, January 2016.

¹³ European Commission, State Aid SA.37045 (2015/N) – United Kingdom, *Government support to the Thames Tideway Tunnel project*, August 2015.

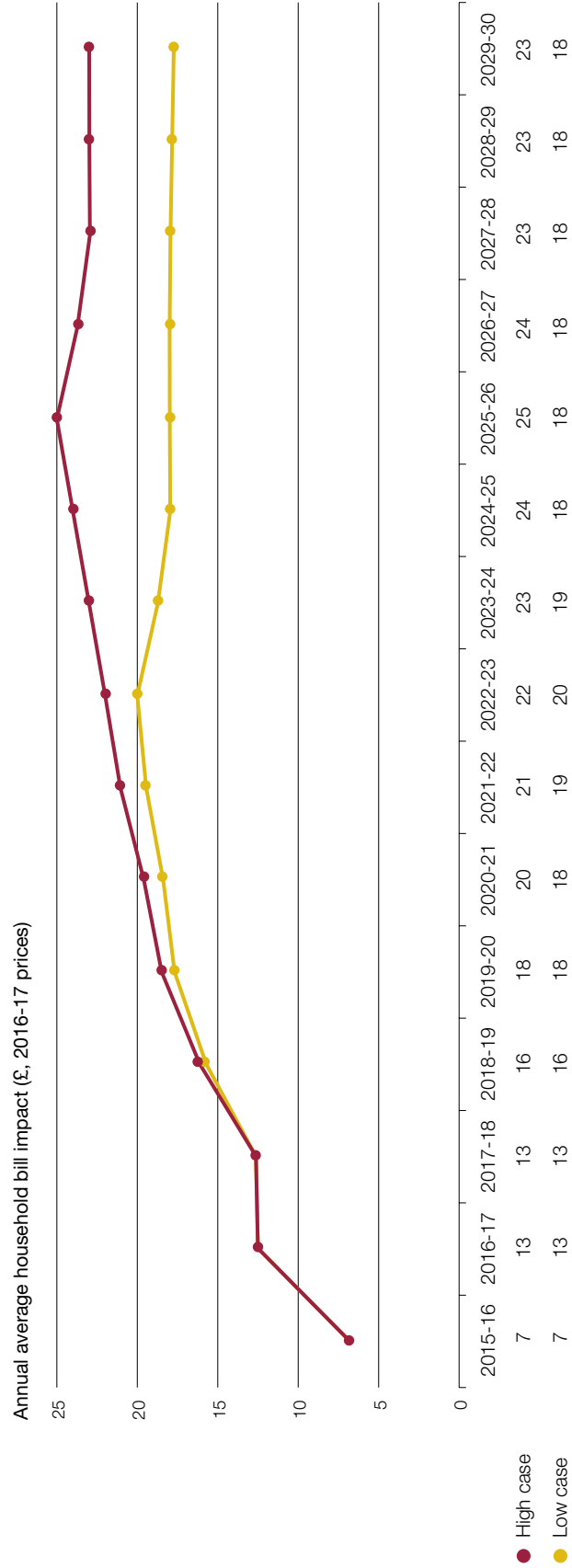
¹⁴ Equity is provided by a consortium of investors: Allianz, Dalmore Capital Limited, INPP, DIF and Swiss Life. Debt investors include a £700 million European Investment Bank loan, a £1 billion committed revolving credit facility provided by several banks, and bond issues totalling £450 million.

¹⁵ Written Ministerial Statement, Hansard, 3 November 2011. Available at: www.publications.parliament.uk/pa/cm201011/cmhansrd/cm111103/wmstext/111103m0001.htm

Figure 12

Forecast customer bill impacts for the Thames Tideway Tunnel

Average annual household bills for Thames Water customers already include £13 for the Tunnel, with peak bill impact expected to reach £20 to £25



Notes

- 1 Illustrative profiles show potential impact on average household bills over time of variations in construction cost and market interest rates.
- 2 The declining profile of the Tunnel's bill impact after each peak reflects the assumed contribution of land sales to lowering customer bills.

Source: Thames Water

Estimated benefits

3.9 The Department estimates that the benefits of the Tunnel will exceed the costs, although both are uncertain. Cost-benefit analysis was not critical to which option was selected, but provides important information on whether the overall benefits justify the costs. The Department estimates that the benefits of the project will be between 1.8 and 3.1 times greater than the costs. The benefits estimate was based on responses from a 2006 survey which asked 875 respondents in England how much they would be willing to pay per year for the package of aesthetic, ecological and health benefits the Tunnel was predicted to deliver.^{16,17} These willingness-to-pay valuations have been extrapolated to cover all English households over 120 years based on their demographic characteristics and distance from the Tideway. Approximately 60% of the estimated annual benefits accrue to households outside of Thames Water's service area, although only Thames Water customers will pay towards the Tunnel's costs.

3.10 Uncertainty about eventual costs and benefits is expected in major projects, and estimates of both costs and benefits have changed significantly since the Tunnel was first considered as a potential solution (**Figure 13** overleaf). Estimated benefits have increased over time based on assumptions (for example updated demographic data) which extrapolate future willingness to pay from the 2006 survey. The latest cost-benefit analysis has been peer-reviewed and found to be broadly in line with best practice. The project's estimated benefits are, however, highly sensitive to assumptions used to extrapolate from the 2006 survey (**Figure 14** overleaf). The Department's estimate does not reflect some important but uncertain benefits, such as averted fines payable for non-compliance with the Directive.

¹⁶ Eftec, *Thames Tideway – Stated Preference Survey*, 2006.

¹⁷ For instance, reducing the number of times in a year when oxygen levels in the water fall low enough to either kill some fish or prevent migration.

Figure 13

Economic appraisals for the Tunnel, 2005–2015

The benefit–cost ratio for the preferred option has changed over time due to changes in assumptions and scope

	2005	2006	2011	2015
Option name	A (low)	1c	1d	1d
Option description	35km, 5.8m diameter tunnel	32.2km, 7.2m diameter tunnel	25km, 5.6–7.2m diameter tunnel	25km, 5.6–7.2m diameter tunnel
Benefits jurisdiction	Thames Water customers	English households	UK households	English households
Appraisal time frame	60 years	60 years	100 years	120 years
Costs (£bn)	1.2	2.0	4.1	4.1
Benefits (£bn)	5.7	4.0	3.0 to 5.1	7.4 to 12.7
Benefit–cost ratio	4.8	2.0	0.7–1.2	1.8–3.1

Note

1 Costs and benefits have been expressed in prices and values of the base appraisal year and so are not directly comparable.

Source: TTSS, *Cost-benefit Working Group Report*, February 2005; Nera, *Thames Tideway Cost Benefit Analysis*, December 2006; Department for Environment & Rural Affairs, *Costs and Benefits of the Thames Tunnel*, November 2011; Department for Environment & Rural Affairs, *Costs and Benefits of the Thames Tideway Tunnel*, 2015

Figure 14

Sensitivity analysis of the Tunnel's estimated benefit-cost ratio and economic indicators

The economic case for the Tunnel is sensitive to assumptions made about the beneficiary population

Scenario	Benefit-cost ratio	
	Considering benefits to Thames Water households alone	Considering benefits to all English households
Scenario A: 2014 income and population levels fixed for appraisal period	0.7	1.8
Scenario B: Benefits uprated with forecast population growth	0.8	2.2
Scenario C: Benefits uprated with forecast household income	0.9	2.5
Scenario D: Benefits uprated with forecast population and household income growth	1.1	3.1

Source: Efec, *Update of the Economic Valuation of Thames Tideway Tunnel Environmental Benefits*, 2015; National Audit Office analysis

Project risks

3.11 Tunnel construction carries inherent risks to timing and cost because of the project's nature and size, and the number of relationships and interfaces involved. The Tunnel is the largest water and sewerage infrastructure project since privatisation and faces challenges owing to the physical environment in which construction takes place. The main risks in the construction phase are that works could damage surrounding high-value infrastructure, or encounter unforeseen difficulties adding time and expense to the works, as knowledge of ground conditions is imperfect. Customers of Thames Water and the taxpayer are potentially exposed if these risks materialise.

3.12 In our 2014 report, we identified a range of risks around the management of the Tunnel project, and project costs. Some risks relate to activities which have been completed since our last report, while others are still 'live' during construction and beyond:

- **Delivery model risks.** Delivery by a separate infrastructure provider could provide worse (or better) value for money than delivery by Thames Water. As Thames Water was not an investor in the project, it could have had limited incentive to keep the price down when procuring construction contracts. The delivery model has now been decided and put in place.
- **Cost estimation risks.** Thames Water may have had incentives to make a case to Ofwat for spending more than needed at the planning stage, because Thames Water receives an allowed return on investments approved by Ofwat. Ofwat and its consultants completed scrutiny of planning cost estimates during 2015.
- **Financing costs and risks.** The infrastructure provider might be unable to secure financing at reasonable cost, or have financing available when needed for contractual payments. Bazalgette has arranged initial finance, although it may need to access further finance during construction, and the GSP (paragraph 3.16) reflects this risk.
- **Construction costs and risks.** Tunnel construction involves risks of poor performance, and unexpected events (for example natural disasters, or construction causing damage to surrounding infrastructure) which are unlikely but carry very high costs which can make these risks impossible or very costly to insure. Financial incentives for contractors to complete works early may increase the probability of these risks materialising, although there are potential benefits of finishing sooner, such as reduced programme costs and risk of fines.
- **Operational risk.** The UK could face fines for continued breach of the Directive, and costs of remedial measures, if the completed Tunnel does not operate as intended. The £4.2 billion cost of the Tunnel does not include running costs after construction, and delivering the Tunnel to time and budget should not be achieved at the expense of excessive ongoing costs after completion.

3.13 Our previous work on major projects identifies common causes of project failure or cost overruns, including: over-optimistic assumptions; technical challenges not recognised; limited understanding of interdependencies and related projects; short-term financial decisions adding to longer-term costs; and failures in relationships with contractors or in the contractor delivery model.

3.14 The Tunnel project arrangements mitigate against these (paragraphs 3.19 to 3.23), for example the project benefits from the experience of the Crossrail and Lee Tunnel construction projects, as well as incentives to promote collaboration between contractors and time and cost savings. But some risks such as cost overruns and contractor failure from poor project management could materialise in the construction phase. The Department and Ofwat will need to continue to monitor the project carefully so they can discuss any evidence of these factors with those delivering the project at a sufficiently early stage.

The Government Support Package

3.15 The government's provision of the GSP to Bazalgette is aimed at mitigating some risks, and transferring liability to the taxpayer if those risks materialise. The Department concluded that private delivery of the project would not be financially viable without some form of government support, because of the scale of the project risks and the implications for financing costs that customers would face. Support is being made available to the building of the new nuclear power station at Hinkley Point, for similar reasons.

3.16 Under the terms of the GSP, which expires when the three-year post-construction project testing period is expected to be complete in February 2027, the Department has agreed to provide financial support in certain limited circumstances:

- **Cost overruns.** The project's target price is £3.2 billion. The Department concluded that Bazalgette's potential investors needed to know the risks of cost overruns and the extent of their liability. The Department has set a cost overrun threshold of £4.1 billion, or £960 million (30%) above the target price: if Bazalgette's costs exceed this threshold, the Department agrees (under the 'Contingent Equity Support Agreement') to either provide equity to Bazalgette; or discontinue the project and pay compensation.
- **Disruption to capital markets.** The Department agrees to lend to Bazalgette if economic or political events make it unable to access debt capital markets as planned. A 'Market Disruption Facility' commits the Department to providing short-term liquidity on commercial terms. In the event of disruption to capital markets, the Department would be liable to provide a short-term loan of between £100 million and £500 million, exposing it to the risk of Bazalgette not repaying the loan.

- **Indemnity.** The Department agrees to provide an indemnity to Bazalgette on commercial terms to cover for liability claims which exceed the company's commercially arranged insurance limits or where insurance is unavailable. Bazalgette requires an indemnity for accidental third party injuries or deaths, or damage to project assets or third party property. A 'Supplemental Compensation Agreement' (SCA) sets out the terms under which this indemnity is provided. The Department would be liable for claims above £2.26 billion per event for damage to construction works, and £750 million per event for third party death, injury or damage.
- **Compensation for discontinuation.** The Department agrees to pay specified compensation to investors in the event that it decides to discontinue the project. The Department has rights under specified circumstances, to withdraw the GSP, which would likely mean that the project could not be completed. Compensation would be linked to allowed project spend incurred, and the cost of breaking investors' hedging contracts.
- **Special administration.** A regime is in place if Bazalgette goes into special administration and remains there for 18 months. The 'Special Administration Offer Agreement' provides for the Department to offer to purchase Bazalgette on whatever terms the Department feels appropriate (or to discontinue the project and pay compensation, as above).

3.17 The Department considers that a call on the GSP is highly unlikely, although it estimates that the impact could be very large if risks materialise. Because some support package elements involve lending or equity finance, which would attract fees, the net financial impact on the taxpayer of providing the GSP is difficult to predict. The Department estimates that government's total exposure in the event of its 'reasonable worst case' scenario could be as high as £6.6 billion if several risks materialised. This 'reasonable worst case scenario' would also result in customers, shareholders and contractors experiencing financial losses (**Figure 15** overleaf).

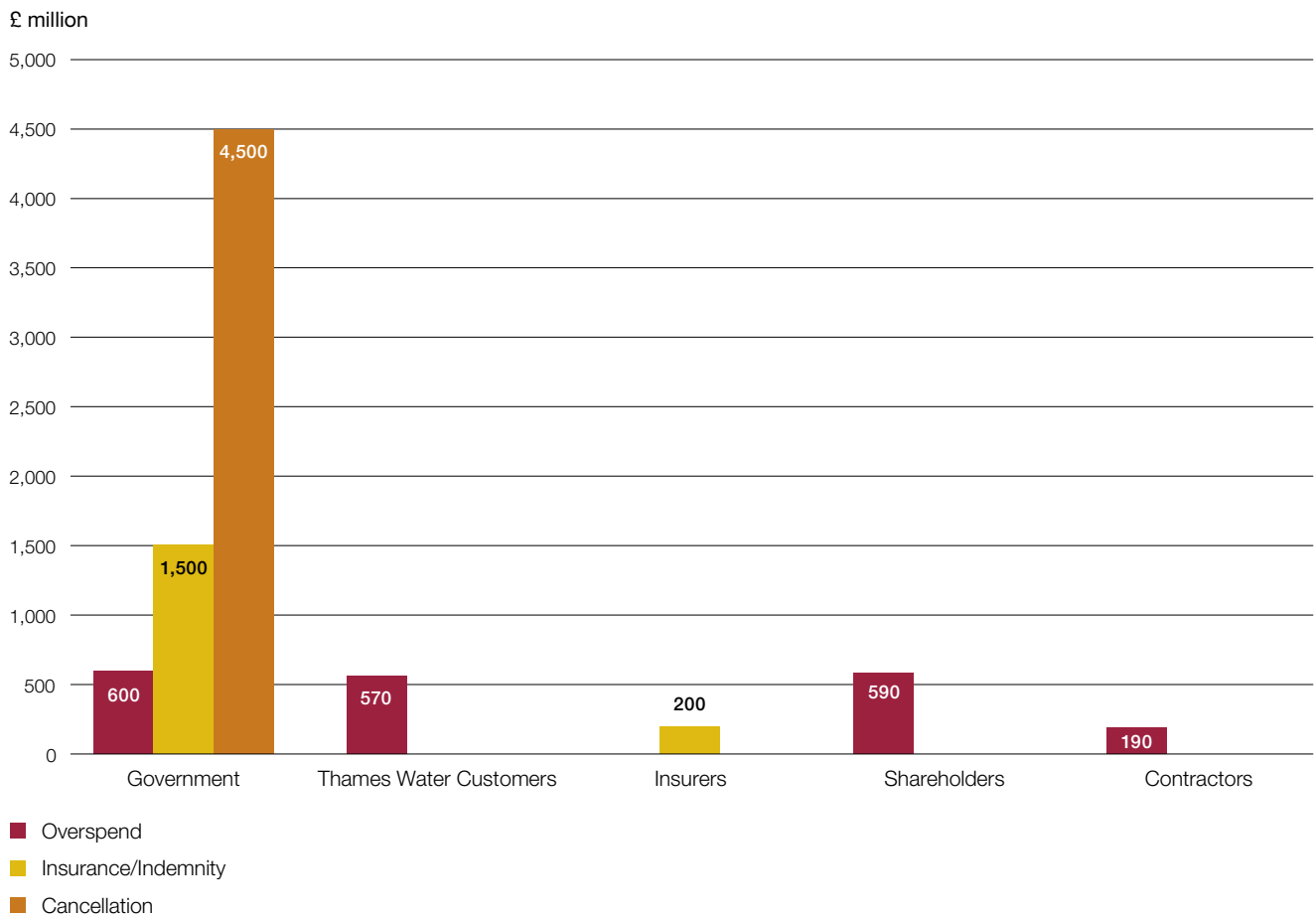
3.18 The Tunnel is one of a number of major infrastructure projects where the government has provided contingent support to facilitate private delivery. The National Infrastructure Plan indicates that the government is becoming increasingly dependent for delivery of major public infrastructure on private finance, and on government support to ensure that sufficient private finance is raised. This can be seen in both taxpayer-funded infrastructure, and in other projects paid for by customers such as the planned nuclear power station at Hinkley Point. As we stated in our 2015 report on the UK Guarantee Scheme,¹⁸ government needs to maintain rigorous and objective approaches to ensure that guarantees – and other support – are genuinely needed and that the projects supported bring significant public value.

¹⁸ Comptroller and Auditor General, *UK Guarantees scheme for infrastructure*, Session 2014-15, HC 909, National Audit Office, January 2015.

Figure 15

Costs incurred in the Department's 'reasonable worst case' scenario

Government would bear £6.6 billion of the costs in its 'reasonable worst case' scenario, with customers funding another £0.6 billion



Notes

- 1 The scenario envisioned assumes government indemnity is called on and a late discontinuation of the project, in which customers only fund their share of overspends up to the 30% threshold, whereupon government provides contingent equity.
- 2 Cancellation costs include £0.4 billion hedging breakage costs.

Source: National Audit Office analysis of the Department's estimates

Success factors and mitigation arrangements

3.19 The project will be successful if the Tunnel delivers the Department's strategic objectives while risks and costs are managed. Contractual arrangements for costs and payments (including 'pain/gain sharing' of cost variations between customers, contractors and shareholders) provide Bazalgette and its contractors with financial incentives to deliver on time and manage the risks of cost overruns.

3.20 Contractors will be rewarded financially for achieving time milestones and cost savings, where doing so achieves a cost saving for the overall project. Conversely, financial penalties will be applied for late completion or cost overruns. Although both contractors and equity investors are shielded from the full extent of any overspend or insurance claims on the project, their overall returns on the project will be higher if these do not occur. Contractors will be liable for deficiencies in their works for 12 years after completion, and the Environment Agency and Ofwat can take enforcement action against both Bazalgette and Thames Water if either company fails to meet its obligations with respect to the Tunnel.

3.21 Under Ofwat's regulatory framework, customers and companies will share in gains from lower than expected costs, and in losses if costs are higher than expected:

- **Bazalgette.** Customers are liable for 60% of overspends between the target price of £3.2 billion (in 2014 prices) and the £4.1 billion cost overrun threshold, subject to Ofwat agreement that overspends have been efficiently incurred. Customers will share in 70% of the benefit of any underspends against the target price. The contractors will share losses from overruns in their sections equally with Bazalgette up to a limit of 25% of the respective contract's value.
- **Thames Water.** Customers will absorb 50% of the impact of both over and underspends on the Tunnel-related expenditure in Thames Water's 2015–2020 business plan. Customers will also share in 100% of any gain or loss on the proceeds from sales of excess land after construction ends.
- **Alliance agreement.** To promote cooperation, three main works contractors together with Thames Water are collectively financially incentivised through a rewards and penalties regime to achieve cost targets and time milestones during the construction period.

3.22 The Department has a monitoring framework for project progress and risks. Governance arrangements include quarterly meetings involving key project stakeholders, and regular meetings between ministers and officials to monitor progress throughout construction. The Department has appointed a loss adjuster, Crawford & Co., to ensure any claims made under the insurance element of the GSP are fair. Independent technical assessors (Mott MacDonald) and technical advisers (OTB Engineering) will provide quarterly assessments on Bazalgette's reports on progress and project costs, with the latter reporting exclusively to the Department. These assessments fulfil a dual role, enabling Ofwat to identify and disallow expenditure which has not been agreed, and providing advance warning of a call on the GSP so the Department can make appropriate preparations.

3.23 The government can restrict Bazalgette's access to the GSP and impose financial disincentives for specified circumstances (such as Bazalgette breaching financial covenants) if the company does not correct the situation in accordance with the remediation regime. The Department has no executive role in managing cost control on the project, but where forecasts indicate a project-level overspend, the Department can require Bazalgette to produce a mitigation plan to reduce or correct the overspend.

3.24 The Tunnel is expected to start delivering benefits by 2024 and to deliver optimised performance after the testing period ends in 2027. Our assessment is that a risk remains that the UK is fined for non-compliance with the Directive prior to this period, despite construction work starting and the prospect of the UK leaving the European Union. The European Commission told us that they have not yet reached a decision on whether to seek fines. In London's case, the scale and complexity of the project and the UK government's stated intention to leave the European Union create uncertainty over this issue. In principle, the UK would be liable to pay such fines while still a European Union member. A range of matters, including any post-exit implications of any judgments of the Court of Justice of the European Union concerning the UK, will be subject to the forthcoming Article 50 negotiations with the European Union. We have not audited or considered the effects on this project of leaving the European Union.

Appendix One

Our audit approach

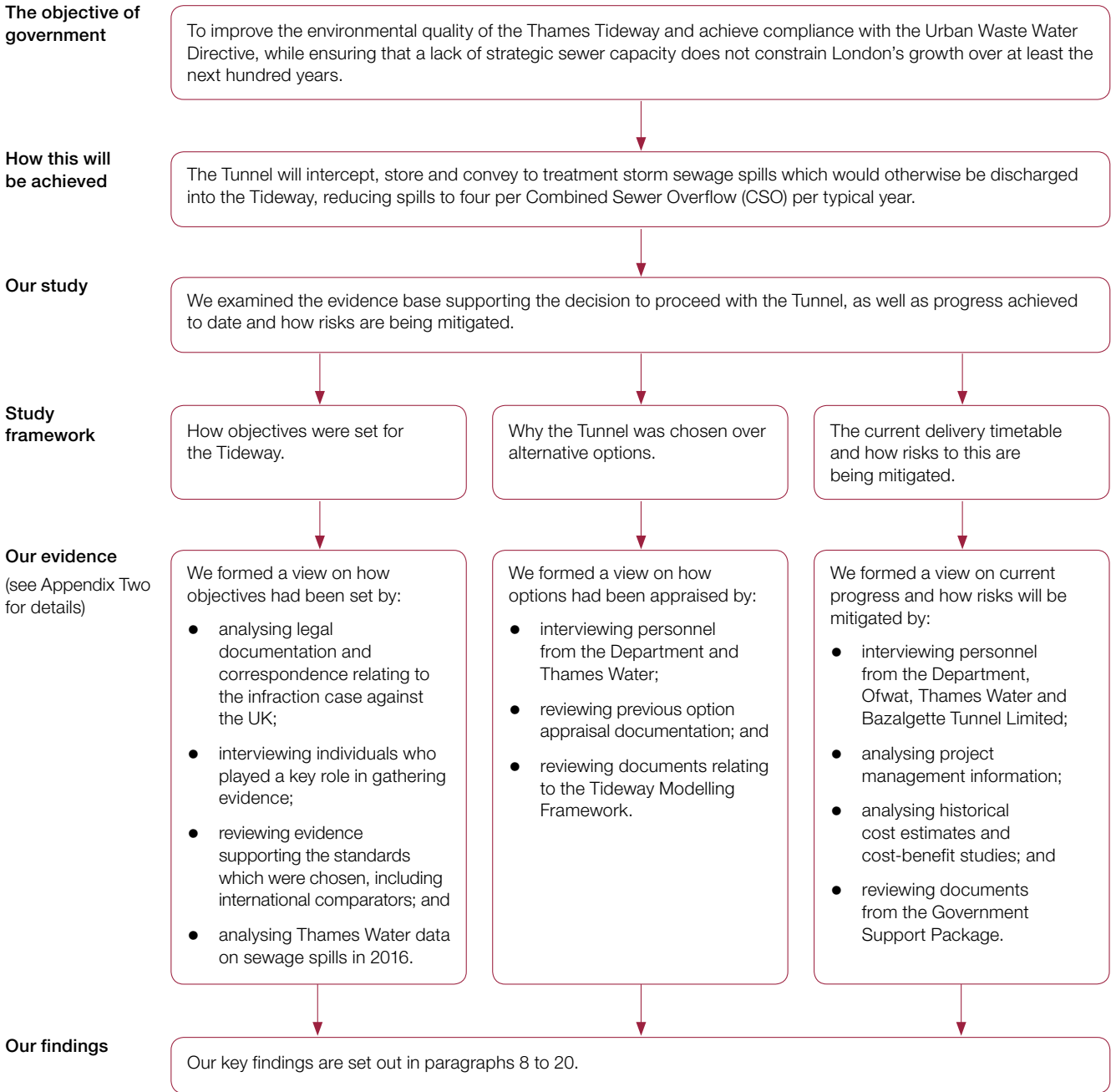
Scope

1 This report examines the development of the Thames Tideway Tunnel. Our review of progress sought to answer the following questions:

- What was the evidence base underpinning the objectives which were set for the Tunnel, and why was it chosen over alternatives?
- What is the current state of progress on the project, including expected completion and costs for Thames Water customers?
- What are the main risks to Thames Water customers and the taxpayer during the construction phase, and how are these being mitigated?

2 Our audit approach is summarised in **Figure 16** overleaf. Our evidence base is described in Appendix Two.

Figure 16
Our audit approach



Appendix Two

Our evidence base

- 1 In examining these issues, we drew on a variety of evidence sources.
- 2 We interviewed relevant individuals from organisations involved in the project, including: the Department, Ofwat, The Environment Agency, The European Commission, Thames Water, and Bazalgette Tunnel Limited.
- 3 We reviewed a range of documents to support our findings, including:
 - legal advice received by the Department in relation to the Urban Waste Water Treatment Directive and some records of communications with the European Commission, to understand the UK's legal obligations;
 - historical option appraisals and cost-benefit analyses relating to the Tunnel and alternative options, in order to understand why the Tunnel had been chosen as the preferred option;
 - documentation on the Tideway modelling suite, including calibration and other quality assurance reports, and related emails, to understand the level of assurance which had been gained over the modelling; and
 - project management reports detailing the state of progress and risk mitigation.
- 4 We performed data analysis on 2015 and 2016 sewage discharges data from five of the largest combined sewer overflows collected by Thames Water in order to estimate the number of spills which had lately occurred along the Thames Tideway from these overflows. Thames Water and the Environment Agency define a 'spill' differently:
 - The definition used by Thames Water counts one spill for any 24-hour period in which there is some discharge. A new spill is counted if discharge occurs after a 24-hour period of no discharge.
 - The definition used by the Environment Agency is that one or more discharge overflow events within a period of 12 hours or less will be considered to be one spill, one or more discharge overflow events extending over a period of greater than 12 hours up to 36 hours will be considered to be two spills. Each subsequent 24 hour duration counts as one additional spill and the whole of the 24 hour block is included.

For the purposes of estimating spills, we used the Thames Water methodology for consistency with the way estimated spills have been reported in Thames Water's updates along the project's lifetime. The choice in methodology has a material impact on the number of spills counted. For instance, the Tideway modelling forecasts that discharge counting at Hammersmith Pumping Station CSO with sewage treatment works improvements and the Lee Tunnel would result in 55 discharges with the Thames Water method and 93 discharges with the Environment Agency method.

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